This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

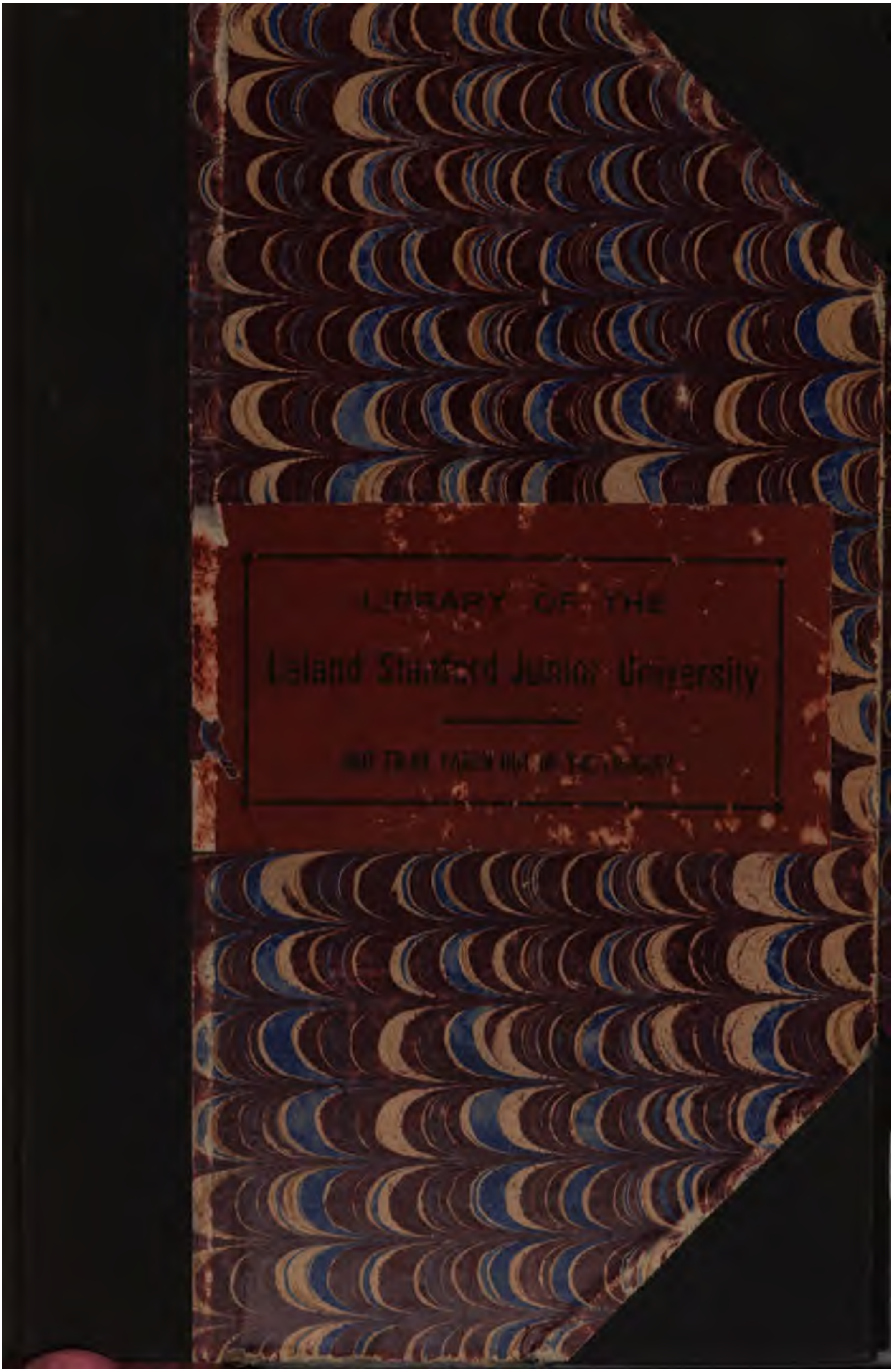
+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

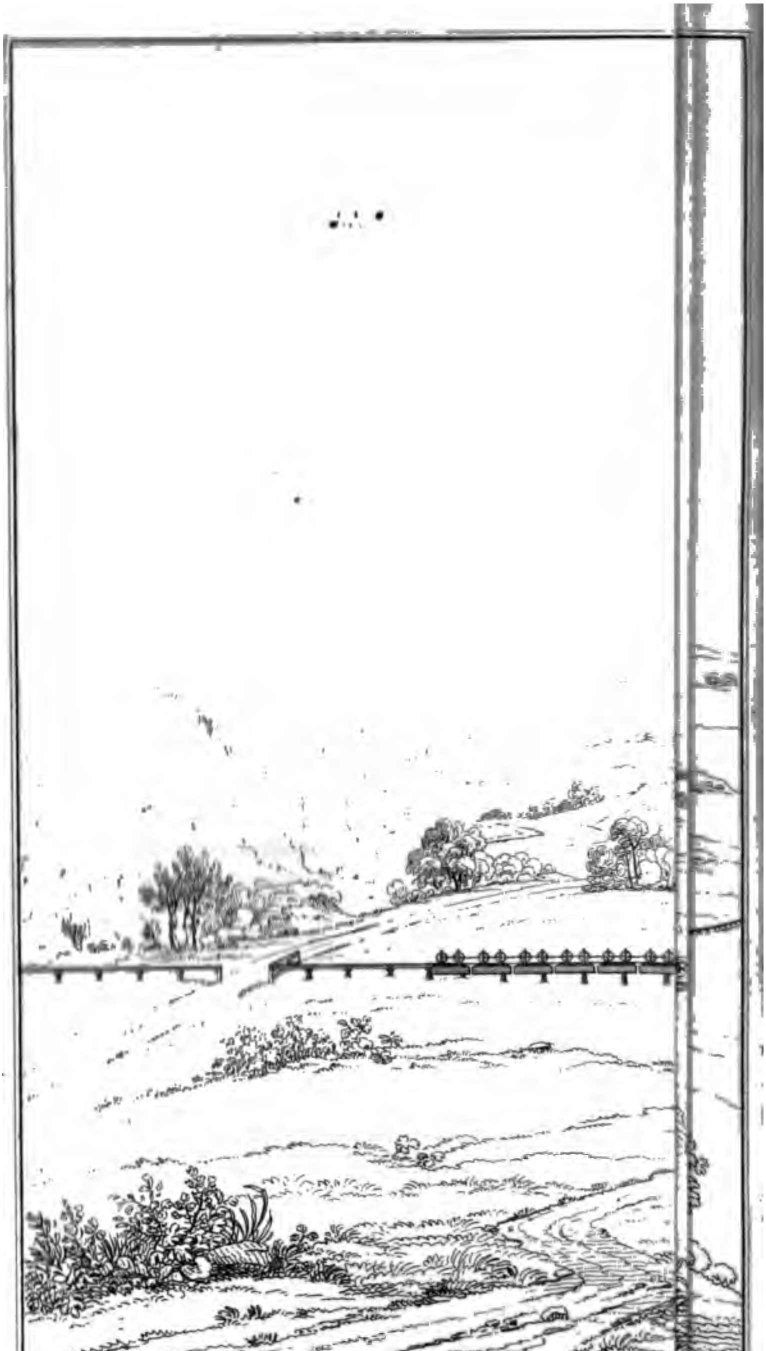


LIBRARY OF THE
Leland Stanford Junior University

NOT TO BE TAKEN FROM THE LIBRARY.

The Hopkins Library
presented to the
Leland Stanford Junior University
by Timothy Hopkins.

14 26840



H.P. I.Gower del

sculp

DESCRIPTION

OF A

RAILWAY ON A NEW PRINCIPLE;

WITH

OBSERVATIONS ON THOSE HITHERTO CONSTRUCTED.

AND

A TABLE,

SHEWING THE COMPARATIVE AMOUNT OF RESISTANCE
ON SEVERAL NOW IN USE.

ALSO

AN ILLUSTRATION OF A NEWLY OBSERVED FACT RELATING TO THE
FRICTION OF AXLES,

AND A DESCRIPTION OF

AN IMPROVED DYNAMOMETER,

FOR ASCERTAINING THE RESISTANCE OF FLOATING VESSELS AND
CARRIAGES MOVING ON ROADS AND RAILWAYS.

By **HENRY R. PALMER**, Civil Engineer,
MEMBER OF THE INSTITUTION OF CIVIL ENGINEERS.

WITH PLATES.

LONDON:
PRINTED FOR J. TAYLOR,
AT THE ARCHITECTURAL LIBRARY, HIGH HOLBORN.
1823.

LELAND STANFORD JUNIOR
LIBRARY
UNIVERSITY.

H.3462.

LONDON:
PRINTED BY JAMES MOYES, GREVILLE-STREET.

PREFACE.

In submitting to the public a method of conveyance differing altogether in principle from any that has before been constructed, I am not unconscious of the difficulties to which prejudice will expose me. But having submitted my plan to such tests as were satisfactory to many of the most eminent Engineers and men of science, I am encouraged by their opinion, and by my own conviction deduced from extensive observations on similar works, to publish a description of it; and that the nature and peculiarities of my plan may the better be understood, I have introduced some remarks on the methods now generally used.

Obstacles to the adoption of the new method may occur, which may not appear to be provided for; but, I trust, a little reflection will evince the impossibility of illustrating all possible cases, without rendering the description too long and tedious. The principle, I venture to assert, admits of very extensive application, yet I would not have it thought that I advise it for every situation, or with the presumption of entirely superseding all former methods.

In some situations my plan will be productive of considerable advantages, while in others it would be inferior to the ordinary construction. The nature of the country, and purposes required, can alone decide the preference.

Very little has been written on the subject of railways, and I know of no work which treats of the several kinds comparatively, or points out the difference of resistance upon them. Such experiments as have been published, are too indefinite for practical purposes. They have simply stated the effect which a horse has produced in each case, without either describing the construction of the railway or its inclination with sufficient precision. There is not only a great inequality in the strength of different horses; but the same horse being capable of producing a much greater effect during a short time, than he can continue day after day successively, the exertion of a horse is not, therefore, an useful standard, more especially in the absence of other particulars of equal importance. The table which is hereafter given therefore refers only to some of those railways which have come under my own observation; and although it does not exhibit a comparison of the original effect which might have been produced upon them when new, or the comparative value of their original construction, it describes them in their present state, and points out the importance of a strict attention to the construction and condition of all such works.

Note. — A specimen of my plan may be seen at Mr. Smart's, Pedlar's Acre, near Westminster Bridge.

13, *Abingdon Street*, *Westminster Bridge*,
May 23, 1823.

CONTENTS.

Page

General Remarks 1

Observations on Railways 6

Illustration of a newly observed fact relating to the friction of axles 21

Description of an improved Dynamometer 26

Table of resistance on several Railways 29

Description of a Railway on a new principle 33

Outline of the principle 34

Advantages to be derived from such an arrangement 41

Details 43

Of loading 48

Of unloading .... *ib.*

Branches, and communicating therewith 51

Passings 52

Crossing roads .... *ib.*

Crossing rivers, and other water courses 54

Junctions with other means of conveyance 56

Description of the frontispiece 57

GENERAL REMARKS.

THE importance of inland communication is so generally acknowledged, that no arguments need be adduced in favour of an attempt to promote it; every individual is either directly or remotely interested in its improvement.

There are but few articles of the first necessity whose nominal value is not greatly dependent on facility of conveyance; and this remark applies still more to the numerous articles of luxury which, introduced at first by the prodigious wealth and the high degree of refinement this country has attained, are now by habit rendered indispensable. The various improvements in our manufactures would have been much less valuable, (and, in some cases, even useless) had not the means of conveyance received a proportionate advancement; the charge of carrying the raw material to the manufacturing district, and the manufactured article to the market, forming no small proportion of its price to the consumer. To the same improvement may also be attributed the increased use of the various minerals and metals which might otherwise, for the most part, have remained in their natural beds.

Of the several methods of conveyance, navigation has been preferred as the most economical; and where natural rivers have not existed, or where they have not been applicable to the purposes of conveyance, artificial canals have been executed, and that already to a considerable extent. But amongst the variety of localities which the surface of the country presents, there are many in which canals are impracticable or too expensive; and in such cases Railways have been adopted, but at the same time with a conviction, that the effect which could be produced upon them would be inferior to that on which they were intended as a substitute; and therefore the natural peculiarities of the surface have determined, in a great degree, the comparative advantages of certain districts in regard to conveyance. But canals themselves have not yet yielded advantages to that amount which, at first thought, they appeared to hold out. They cannot directly communicate with every town, or individual property, for whose use they are intended; and branch lines of communication, on some other principles, become indispensable. The distance and other localities of the several positions referred to, together with the expense of transhipping from one kind of conveyance to the other, necessarily precludes them from deriving the full benefit of those works.

Railways have been frequently recommended, and adopted as branches to canals; but the nature of them is such as to require certain localities in the situation to render their application profitable. When the trade has to ascend over an inclination exceeding certain limits, they offer but little advantage over a common road; but, on the contrary, where the trade has to descend, and that at a certain inclination, the effect on a well-constructed railway is considerable, and it becomes a profitable undertaking. But in the use of railways to general purposes, the inconvenience arising from transhipping is still observed, as in the case of canals, although in a less degree; as a great proportion of the traffic must be ultimately conveyed to its destiny from the main line, communicating by means of the common road; and thus, although a district may have the advantage of a canal, and a situation not very distant from the canal be possessed of a branch line of railway, the dispersion of the traffic must ultimately take place by means of the common road, and thus the goods conveyed between the extreme points may undergo four loadings and unloadings before they arrive at the place of their consignment. They must first be conveyed to the canal, perhaps by the common road; from the canal they are transferred to the railway; and having proceeded as far as its direction is useful, are again transferred to the road.

The delay and expense of these several changes may more than compensate for the advantages which canals and railways hold out over common roads, unless the distance exceed certain limits ; and, hence, goods are frequently conveyed six or seven miles by the public road in preference to a canal.

The connexion of the several means of conveyance with each other is, therefore, a very important branch of the subject ; and if this were rendered less obstructive, canals would be considerably benefitted, and railways much more encouraged.

Notwithstanding the obvious importance of railways, both for public and private purposes, it would seem that an acquaintance with the nature of them is much less general than might have been expected, as their useful effects have been so variously estimated. I shall, therefore, offer some remarks upon them previous to entering upon the description of my new method of conveyance, which classes in their denomination.

lway excels
nent of the
e second in
and smooth.
arious forms
apes of their
ed in several
hed generally
hat first used,
ates of which are
ches in breadth,
de to direct the
heels of the car-
e breadth being
of the material
re called Edge
an the former,
wo inches and
t a little above
that account,
upon them.

They have no flanch to direct the
surface is either flat, or a little co
flat, the wheels are provided with
directs their motion ; if curved,
formed with a groove, correspon
the curvature of the rail, and th
tinct flanch is necessary.

The rails are made of vario
composed of cast iron, that mo
three feet, some extend to six fe
leable iron, from ten to twenty f
are connected together upon a sl
at each joint. The sleepers for
reach from two opposite joints, an
of wood, which then constitutes t
The blocks are pieces of stone,
to eighteen inches square, som
depending on the weight of eac
riage ; the two opposite of these
connected together by a cross
but the two lines of rail are m
independent of each other.

Railways are either level

circumstances require, provided the nature of the country admits of a choice. When the trade is great or nearly equal in both directions, as may be expected in public lines, the railway is, if possible, made level : where the trade is all in one direction, and that downwards, as from a mine to a port, the line is made inclined, and, if possible, the inclination is such that the resistance of the loaded carriage downwards is equal to that of the empty carriage returning upwards. The effect which can be produced on a railway is estimated by the quantity of weight which a given power can draw upon a level surface of it ; the resistance then being only such as arises from imperfection of the parts, and the friction of the axles of the carriages ; any additional resistance occasioned by an ascent or inclination being only a subject of calculation. But as the force required to draw any weight up a given inclination is in proportion to the weight itself, it follows that the angle of inclination will be in proportion to the resistance of surfaces.

And, in the case of an inclined railway whose traffic is all in one direction, it will be comparatively of small importance to reduce the resistance of surfaces, in order that a given power may convey a greater load downwards, if the same be not equal to return upwards with the empty carriages. In like manner, in proportion to the quality of surface obtained, a regularity of line must be observed. As every bend occasions considerable resistance, and that in proportion to the weight conveyed, a given power may be capable of drawing a considerable weight along a straight line, but may be incapable of continuing the same effect through a bend or curve.

The great difference in effect produced by the different railways, not only on the peculiarity of their parts, but also the difference in the arrangement of the lines in respect to their inclination and regularity, and an apparently trifling difference in these varies the result in a greater degree than is usually ascribed to it.

The natural irregularities of the country, the

OBSERVATIONS ON RAILWAYS.

The first principle in which a railway excels a public road, is in the arrangement of the plane intended for the surface; the second in the surface itself, as being more hard and smooth.

Railways are constructed in various forms as respects the dimensions and shapes of their parts; the parts are also connected in several ways; but they may be distinguished generally into two kinds. The one, and that first used, is called a Tram Road, the plates of which are usually flat and about four inches in breadth, having a flanch on the inner side to direct the motion of the wheels. The wheels of the carriage are narrow on the rim, the breadth being diminished as far as the strength of the material will justify. The second kind are called Edge rails. These are of less width than the former, being usually from one inch to two inches and a quarter in width. They project a little above the surface of the ground, and, on that account, are less liable to dirt, &c. lying upon them.

They have no flanch to direct the wheel; their surface is either flat, or a little convex. When flat, the wheels are provided with a flanch which directs their motion; if curved, the wheel is formed with a groove, corresponding nearly to the curvature of the rail, and therefore no distinct flanch is necessary.

The rails are made of various lengths; if composed of cast iron, that most common is three feet, some extend to six feet; if of malleable iron, from ten to twenty feet. The rails are connected together upon a sleeper or block at each joint. The sleepers for the short rails reach from two opposite joints, and are generally of wood, which then constitutes the foundation. The blocks are pieces of stone, about sixteen to eighteen inches square, sometimes more, depending on the weight of each loaded carriage; the two opposite of these are sometimes connected together by a cross sleeper of iron, but the two lines of rail are more frequently independent of each other.

Railways are either level or inclined, as circumstances require, provided the nature of the country admits of a choice. When the trade is great or nearly equal in both directions, as may be expected in public lines, the railway is, if possible, made level : where the trade is all in one direction, and that downwards, as from a mine to a port, the line is made inclined, and, if possible, the inclination is such that the resistance of the loaded carriage downwards is equal to that of the empty carriage returning upwards. The effect which can be produced on a railway is estimated by the quantity of weight which a given power can draw upon a level surface of it ; the resistance then being only such as arises from imperfection of the parts, and the friction of the axles of the carriages ; any additional resistance occasioned by an ascent or inclination being only a subject of calculation. But as the force required to draw any weight up a given inclination is in proportion to the weight itself, it follows that the angle of inclination will be in proportion to the resistance of surfaces.

And, in the case of an inclined railway whose traffic is all in one direction, it will be comparatively of small importance to reduce the resistance of surfaces, in order that a given power may convey a greater load downwards, if the same be not equal to return upwards with the empty carriages. In like manner, in proportion to the quality of surface obtained, a regularity of line must be observed. As every bend occasions considerable resistance, and that in proportion to the weight conveyed, a given power may be capable of drawing a considerable weight along a straight line, but may be incapable of continuing the same effect through a bend or curve.

The great difference in effect produced by the different railways, not only on the peculiarity of their parts, but also the difference in the arrangement of the lines in respect to their inclination and regularity, and an apparently trifling difference in these varies the result in a greater degree than is usually ascribed to it.

The natural irregularities of the country, the interception of the line by water-courses, the imperfections of soil, and positions of private property, constitute the principal obstacles in the way of adopting that line which would be most profitable. The natural impediments are of course only to be surmounted by the skill of the projector; but with a view to the saving in the first cost of the work, the result is sometimes nearly defeated. But the position of private property is usually the greatest of these obstacles. Lines of communication often suffer much diminution of effect, even at the expense of overcoming some natural obstacle, simply to avoid an alteration in the shape of some pasture. An intrepid determination to yield neither to the right or left where an obstacle presents itself, cannot be approved of; but that mistaken economy which gives way to every trifling impediment should be jealously avoided.

Railways differ essentially from canals, inasmuch as the effect which can be produced upon them bears a strict relation to the quality of their execution. On a canal the resistance of the fluid is nearly all that has to be overcome, and that with a small velocity is comparatively trifling, let the workmanship of the canal be what it may. But on railways, the whole resistance on a level line, except the friction of the axles, arises from *imperfections which are not essential to the principle:* if, therefore, the best possible line be chosen, much remains to be encountered.

It is, perhaps, too common an error which attributes the advantages of railways over common roads to be derived from the material employed. It is safe to infer that such a notion is not uncommon, when we observe an almost total neglect of the adjustment of the rails, and of the construction of the carriages. I have seen one railway, or rather a tram road, having a fall of a quarter of an inch to a yard, down which it required the full exertion of a horse to draw a ton and a half, where, with the same materials properly disposed, the carriage would have descended by its own weight. The railway referred to cost as much originally as one on which the same power might have produced five times the effect.

If a plane be perfectly hard, smooth, level, and straight, and the wheels of a carriage perfectly hard, smooth, and cylindrical, the motion of such carriage would be impeded only by the resistance occasioned by the friction of the axles. And, therefore, in the construction of railways, we must have a correct idea of the nature of every circumstance which contributes to make up the whole resistance seen in practice, that we may the better perceive the value of a correct construction. By exerting due pains in the formation of these works, a reduction of resistance is not all that is accomplished. Every imperfection which occasions a resistance also exposes the work to injury, and the imperfections are liable to increase ; *and thus the work itself becomes destroyed, rather by its own imperfection than the operations for which it is intended.*

A railway and its carriage form together one machine; it is only from the extent of one of its parts that they are separate in idea, and no excellence in the one will compensate for an imperfection in the other. The parts of the plane, and those of the carriage, are therefore each of an equal importance, and must invariably be considered in relation to each other. The improvements are not to be obtained from a perfection in any one part, while the others are neglected, but from a due attention to the construction and proportion of all.

With a view to economy in the quantity of materials, the load is divided into a number of parts, and distributed amongst so many carriages; therefore, the power that gives the motion is necessarily at a great distance from some of the carriages, and if the line be irregular, the power will not be exerted in the direction of the motion of the carriages: their motion will consequently be partly directed by the reaction of the flanches on the sides of the rails, and the amount of that reaction is deducted from the effect which the power might otherwise produce; and as much power as is equal to that reaction is exerted to displace the position of the rails. But it is not enough that the general arrangement of the line be as free as possible from bends; if the parts themselves do not nicely correspond to it, a resistance is encountered which is not necessary in principle. Some arrangement is always necessary to preserve the direction of the carriages. On tram ways, the flanches on the plates serve that purpose; on flat-edged railways, flanches on the wheels are necessary; and the smallest imperfection in the rails will occasion a continual rubbing of the one against the other, *making a resistance greater than that of the imperfection of surfaces*, and every such action tends to disturb or loosen the rails, and the foundation on which they stand.

In tram roads, the rims of the wheels are generally so far out of proportion to the strength of the materials, that, by successive motion, they form a rut or groove in the plates, and ultimately divide them longitudinally into two parts. The object of the small width is principally to pass the obstructions lying upon the rails the more easily. When any such irregularity is once found, the wheels, from other imperfections in the works, do not follow uninterruptedly the courses of those ruts, but are frequently escaping upon the sides of them, and, returning again, act with a violence on the rails, which tends to disturb their position, and produce frequent fractures. In edge rails, the proportion of bearing surface to the weight is frequently too much neglected, and an irregularity is given to the motion, which becomes a resistance, and destroys the parts.

If one general plane be more effectual than another, the parts of it are of like importance. A perfect equality in the stability of every block which supports the line cannot be expected, and, although weakest, may be capable of resisting a dead weight equal to that which may pass over it; the irregularity, or jolting motion arising from the several imperfections, constitutes a force whose effect on the foundation is soon observed. The surface of the rails being near the ground, they are necessarily exposed to dirt, and other extraneous substances lying upon them. This evil is most evident in tram ways, and although inferior on edge rails, those are not entirely free from it, especially when the articles conveyed are at all adhesive in their nature, that, by falling from the waggons, distribute the obstruction on the rails as they proceed. The presence of extraneous substances on the surface of the rails is then not only an obstruction to the motion, but its effect has a continual tendency to destroy the perfection of the plane, and occasion repeated and expensive repairs. The smallest protuberance on the surface, if it be sufficient to change the direction of the motion, is an impediment.

I made an experiment on a branch of the Cheltenham tram road (which was nearly new, and in good condition), with a view to ascertain the difference of resistance occasioned by *dust* lying upon the rails. The carriage and its load weighed five thousand two hundred and sixty four pounds: the rails being swept clean, the resistance was thirty-six pounds; the rails being slightly covered with dust, the resistance was forty-three pounds. Consequently, the difference of resistance to that weight was seven pounds, being upwards of one-fifth increase.

$\frac{5264}{36}$

On the edge railway at the Penrhyn slate quarries, whose rails are convex on the surface, it is usual to carry a butt of water before the train of carriages, which sprinkles the rails in its progress, and washes their surfaces. This railway is upon an inclination of three eighths of an inch to a yard. The train consists of as many carriages as three horses can convey. The power required to draw up the water carriage, at a mean weight, is twenty-one pounds, being seven pounds to each horse; which should be at least equal to the quantity of resistance occasioned by the dust, if the expedient be economical. The same practice is not uncommen on tram ways, but these require it in a greater degree*.

But the Cheltenham experiment which has been referred to, is not to be taken even as an average of those frequently seen in practice. On the main line of the Cheltenham railway, which is on the side of a public road, the superfluous obstacles were considerably greater. The same horse may draw upwards of one ton more on the branch on which the experiment was made than he does in practice on the general line.

Since the several imperfections to which the surfaces of railways are exposed continually derange the position of the foundations, and render the line irregular, destroy the parallelism of the two lines of rails, and ultimately induce repeated fractures and expensive repairs, the adjustment of the rails to their proper position becomes an expensive operation, if strictly adhered to.

---

* The practice of carrying water in front of the train, was suggested by the diminution of resistance perceived during rain. On some tram ways, an additional waggon is attached to a horse during rainy weather.

But the adjustment of railways, as hitherto constructed, is in fact a rebedding of their foundation, and does not admit of that accuracy which perfection desires. If the adjustment of a mill were dependant on similar circumstances for their truth, the motions would soon destroy its parts; the difference in the two cases consists almost entirely in the degrees of complication, and the effect is more strikingly manifest in the one than in the other. Where a careful attention has been paid to retain or correct the position of the parts as they may from time to time have been deranged, the expense attending it, even with the present means, has been amply compensated by the saving in carriage and damage to the works. How much advantage then would be derived from the adoption of some method by which the adjustment may be accomplished with precision, without disturbing the foundation and the rails.

Railways being an improvement on common roads, their superiority was so decisive in regard to economy of draught, that the carriages, at least by far the greater number of them, have been neglected, as if they contributed but little to the resistance. The wheels are applied to use immediately from the foundry, without even being made circular. The axles, the friction of which constitutes a large proportion of the resistance, are most generally of a very inferior kind. When we refer to the great difference of results obtained by different experimenters on the friction of axles, although in every case of such experiments the best materials and workmanship have been employed, it necessarily follows, that a slight difference in circumstances may produce considerable variation in effect.

Being frequently in the habit of measuring the resistance of a carriage on the construction hereafter described, I observed a circumstance which subsequently contributed to throw some new light on this part of our subject; and, as it relates equally to many other objects in practical mechanism, I will state the observations at length.

During a succession of experiments, occasionally for many months, I invariably perceived, that when fresh oil was applied to the axles of the carriage, *the resistance was increased,* and it required the ordinary motion of the carriage for several days to restore the resistance to its usual standard. No other presumption occurred to account for this fact, than the possibility of the oil being better adapted for its office after being some time exposed to use. It was suggested by a scientific acquaintance, that the oil became thickened, or less fluid, after exposure to the air, and was therefore better able to resist the contact of surfaces. In order to prove this, I thickened some oil artificially, by the admixture of a small quantity of bees' wax. But the appearances were the same as before. It then occurred to me that there was not sufficient play, or difference of diameters, between the axle and the nave in which it worked; I therefore had the axles slightly reduced. On again measuring the resistance, I found circumstances as before, but differing in amount, the resistance being slightly increased. I was by this time convinced that the quantity rather than quality of oil occasioned the appearances; to prove which the axles were made perfectly clean, and then simply moistened with oil by the finger previous to inserting them in the wheel. In this state the resistance was again measured, and found to be *similar to the standard usually observed* after the carriage had been some days in motion as before described. It being then proved that the *quantity* of oil occasioned the difference of resistance, the following solution of the manner in which the additional quantity could produce such an effect, appeared reasonable:

Fig. 1.

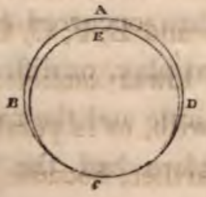
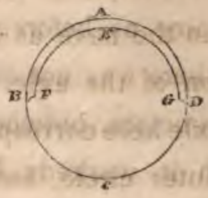


Fig. 2.



Let A, B, C, D, Fig. 1. represent the circle of the hole in the nave of the wheel, and E, C, the section of the axle. The circle E, C, touches A, B, C, D, only in the point C. A very acute angular space then remains between A, E, and C, on either side of E, C. If that space be filled with oil, the oil may be considered as a wedge, and if the outer circle be set in motion, that wedge will endeavour to pass the point C. But it cannot pass in its present form without raising the circle E, C; but E, C, having the weight of the carriage upon it, would resist its passage.

Now this continual and unsuccessful endeavour to pass the point C, will occasion an impediment to the motion.

To put this solution to the test, the axles were formed as in Figure 2. A, B, C, D, is the hole in the nave as before and E, F, C, G, the section of the axle. The lower semicircle of the axle here corresponds with, or is parallel to the outer circle, but no farther, because, *if it corresponded throughout the circle, the axle would* *be liable to jamb, as other experiments have proved.* The coincidence then ceases abruptly, as at B, F, G, D, and the space above, which contains the oil, is not angular, but the quantity of oil which is to pass toward the lower semicircle, is determined at B or D.

On measuring the resistance with the axle thus formed, I found it not increased by any quantity of oil that might be inserted, but by dispensing with the angular space and consequent wedge-like action of the oil, *the resistance was one-tenth less than the former standard.* In cases wherein the difference of diameters is considerable, I do not apprehend the obstruction from the quantity of oil would be of consequence: but it is desirable to make the bearing surfaces nearly to correspond, to obtain a greater *width* of touching surface, and the more perfectly to govern the motion. The form of axle just described is in fact the converse of a well made plummer block used in machinery.

The several kinds of resistance exist in a variety of proportions in the many railways that have been constructed, and, as with public roads and carriages, much ingenuity has been exercised on particular parts of the works, neglecting the rest. The very dissimilar results are therefore not to be ascribed to any one particular defect; but when we know how small a difference in circumstances may materially alter the amount of effect — that in each case the same number of bridges, culverts, drains, cuttings, and embankments, are required, and the same quantity of land occupied, it is often to be regretted that so much effect is lost, only from ignorance or mere negligence.

Perhaps if some accurate means of ascertaining the resistance of roads and railways were on all occasions used, their improvement would be much advanced. The real value of either being then unequivocally compared, the amount of defect could no longer be a matter of mere opinion. The proprietors would then know whether an apparent inferiority arose from the difference of horses or difference of circumstances; and it would be of great advantage to introduce a clause in contracts, which would determine the effect to be produced. The methods by which resistance of roads and railways have been ascertained, have not been sufficiently accurate, or have been too inconvenient for general use. The dynamometers, which denote the resistance by the degree of extension given to springs attached to the carriage, are convenient as portable instruments, but do not denote the measure with the necessary precision. The resistances are not equable from the irregularities of the surface; neither does the force which draws the carriage continue equable. When horses are employed, those instruments are of no service whatever. The effect of the unequal force or resistance occasions a vibratory motion to the indicating point, and we can never have confidence in any result they exhibit. Similar defects are observable in all the instruments I have seen.

Having had frequent occasion to ascertain these resistances, I constructed an instrument which, by removing the imperfection referred to, has been completely successful. The problem was to make such an instrument as would indicate very small differences, but which would not yield *suddenly* to a change of resistance. I therefore connected to a spring dynamometer, a semicircular close copper vessel containing water; at the centre is a spindle, on which an arm or fan is fixed, and which very nearly corresponds with the inside of the vessel. The springs are so connected with the spindle, that they cannot be acted upon without the arm or fan turning upon its centre, and passing through water. In order to pass through the water, the latter must escape by its sides, and the space being extremely small, *it cannot pass rapidly, but will yield to the smallest force.*

By way of exhibiting the difference of resistance upon different railways, I have attached a table containing experiments on several.

The first column contains the articles conveyed; the second, the resistance in proportion to the weight; the third, the whole effect produced, *i. e.* including the weight of the carriage by one horse, or one hundred and fifty pounds, at two miles and a half per hour; the fourth, the useful effect, or the load conveyed, in pounds; the fifth, the same in ordinary measures; the sixth, the inclination, expressed by decimal fractions, on which a railway, whose resistance is equal to that specified, should be constructed, that the resistance of the loaded carriages downwards, may be equal to that of the empty carriages upwards; the seventh, the effect produced under such circumstances; the eighth, the useful effect under the same, the weight of the carriages being deducted. In each experiment, the power of the horse is assumed at one hundred and fifty pounds, moving at the rate of two miles and a half per hour.

Note.—In the inclinations, the weight of the horse itself, as part of the effect produced, is not taken into account, that the table may equally serve where mechanical force is employed. Some allowance must therefore be made where horses are used, but the difference in the inclinations given will be very trifling.

TABLE, exhibiting the amount of Resistance in a straight line upon several Railways, also showing the effect which can be produced by a force of 150 lbs. at two miles and a half per hour, being that exerted by an average good horse, through an ordinary day's work.

		1	2	3	4	5	6	7	8
No. of Exper.	List of Railways.	Materials conveyed.	Resistance in proportion to the weight.	Effect produced on a level by a force of 150 lbs. at 2½ miles per hour.	Useful effect or weight in pounds, carriages deducted.	Useful effect in tons and parts.	Proper inclination for a descending trade.	Effect produced on the proper inclination by 150 lbs. carriages included.	Useful effect on the inclination.
						Ton cwt. lbs.			
1	Llanelly Tram Road, S. Wales,	Coals.	$\frac{1}{59}$	8850	4602	2 1 10	,005958	6 1 92	3 3 38
2	Surrey Tram Road,	Chalk.	$\frac{1}{60}$	9000	6750	3 0 30	,010000	10 0 100	7 10 75
3	Penrhyn Slate Quarries, edge rail road, curved surface,	Slate.	$\frac{1}{87}$	13050	10084	4 10 4	,007237	15 14 68	12 3 12
4	Cheltenham Tram Road,	Coals.	$\frac{1}{90}$	13500	8679	3 17 55	,005263	11 9 4	7 7 27
5	New Branch of Ditto, slightly covered with dust,	Do.	$\frac{1}{122}$	18300	11765	5 5 5	,003883	15 10 53	9 19 67
6	Ditto swept clean,	Do.	$\frac{1}{146}$	21900	14079	6 5 79	,003244	18 11 59	11 18 95
7	Edge Rail Roads near Newcastle upon Tyne,	Do.	$\frac{1}{170}$	25500	17773	7 18 77	,003146	24 9 59	17 1 21
8	Railway invented by H. R. Palmer,	Do.	$\frac{1}{300}$	45000	33750	15 1 38	,002000	50 4 52	37 13 39

Note.—I am indebted to Mr. Grimshaw of Sunderland for the data of No. 7.

It must be observed, that the proportion of real to the useful effect will vary according to the nature of the article conveyed, as on that the proportion of the weight of the carriage to its load depends.

The results due to the assumed power of a horse of course vary from the effect really produced in the ordinary practice on the several railways, on account of the difference of horses employed, and the bends in the courses of the lines. The result due to a level and straight part of Llanelly railway is, according to the table, two tons, one hundred weight, and ten pounds, but, in fact, each horse conveys only one ton and a quarter. Also the effect due to a horse on the Cheltenham rail way, is three tons, seventeen hundred weight, and fifty-five pounds; but each conveys only three tons. And, on the contrary, the effect due to a horse on the edge rails near Newcastle, is seven tons, eighteen hundred weight, and seventy-seven pounds; but the horses employed there, convey eight tons eight hundred weight each, and some of them more.

The second column, exhibiting the proportion of resistance to the load by a fraction, also expresses that inclination on which a carriage would descend in a straight line (having such a resistance) without acceleration.

The proper angle upon which a railway for a descending trade should be constructed, varying with the proportion of the weight of carriages, to the loads they convey; the difference in effect in columns seven and eight, occasioned by a difference of resistance, is not so distinctly exhibited as it might have been, were the same proportion observed throughout. The calculations are deduced from the experiments as they were made, and the latter were performed on one of the carriages which might be considered as an average of the rest usually in operation on the several lines. The three experiments on the Cheltenham railway being with the same carriage, point out very distinctly the difference in effect in a descending trade, which results from apparently slight imperfections, viz. the difference of resistance occasioned by the dust alters the angle of inclination, and the angle being altered, the ultimate difference is *three tons seven hundred weight in one horse's load.*

DESCRIPTION

OF A

RAILWAY ON A NEW PRINCIPLE.

THE leading problem in our present subject is, to convey any given quantity of weight between two points at the least possible expense. The expense of conveyance is compounded of the original cost of the means which are employed, the cost of the repairs to which it is liable, the expense of transporting the articles or of overcoming the resistances to which their motion is exposed, and the cost of loading and unloading the same.

In some instances expedition is necessary to the value of the work; but in all, that the operations should not be exposed to interruption, either by occasional imperfections of the method employed, or by peculiarities of weather.

From what has been before advanced it must be inferred, that our first principle should rather be to remove every thing which is an impediment to the motion, rather than to submit to their existence, and search after the most effectual method of overcoming them; and therefore a line of railway should be as straight as possible; it should be nicely adjusted to that plane which is most profitable; its parts should be as few as circumstances will admit; the touching surfaces should be hard and smooth, and should not be exposed to extraneous matter lying upon or adhering to them: the parts should retain their position; and if, by accident or unavoidable circumstances, any should yield, an adjustment should be provided which admits of accuracy without much expense or loss of time.

As lines of communication are seldom unconnected with others of a different principle, the facility of transferring the goods from the one to the other, must also be regarded as essential.

In order to retain a perfectly smooth and hard surface, unencumbered wih extraneous obstacles to which the rails near the ground are exposed, it appeared desirable to elevate the surface from the reach of those obstacles, and at the same time be released from the impediments occasioned by snows in the winter season. This also appeared to afford a better opportunity of adjusting and retaining the plane. To elevate two lines of rail for the purpose of supporting a carriage, could not be accomplished at a sufficiently moderate expense : I therefore endeavoured to arrange the form of a carriage in such a manner that it would travel upon a single line of rail, without the possibility of overturning. Having then but one line of surface to retain in its right position, and that so high above the ground as to be completely under the command of hand, the adjustments so much required appeared at once practicable. The only question was, In what manner the surface was to be supported at the required height? After considering on various methods, the supporting of it upon posts, piles, or cast iron pillars, seemed best suited, provided they could be fixed with sufficient firmness. It was evident that if these were fixed in the manner they are usually done, sufficient dependence could not be placed upon them; but conscious of the enormous weight which a well driven pile will support without yielding, I examined into the circumstances which were necessary to ensure its stability previous to prosecuting the scheme any farther.

When a number of piles are driven near together, it is known they are not so secure as when at a greater distance; so also a pile whose horizontal section is great, is not so effectual in proportion to its size as a lesser one, because if the space taken up by a pile or any number of them, be greater than the compressibility of the soil admits of, the soil becomes disturbed, loosened, and rises up. The manner of obtaining most resistance from a pile, is therefore to take out such a portion of the soil as to leave only as much to be compressed by the insertion of the pile as the

compressibility of the soil admits without being loosened.

By this means a pile may sustain a much greater vertical pressure than when driven in the ordinary way. The only thing remaining to be done is to secure its vertical position. If its dimensions are capable of resisting a fracture, this may be accomplished by the depth to which it is driven, equally well as with auxiliary supports on the sides. As cast iron appeared best suited for the material of the pillars, (although in some districts stone or wood may be used) and as in the required form it was not adapted for being driven, I have, on the principle of the foregoing observations, adopted a method which has proved completely effectual even under very unfavourable circumstances.

The form of pillar is seen in figs. 1 and 2; its horizontal section is in the form of a cross, and therefore represents four ribs at right angles to each other. A, fig. 1, (see the plate) is a flanch even with the ground; the ribs beneath its flanch

are notched in order to connect with the material surrounding it. The pillar is inserted into the ground about the same distance as it projects out of it, say 2 feet 6 inches each way. A circular hole is made by taking out a portion of the soil first, and completed by letting fall a conical rammer from an engine, like a small pile engine; this rammer then perfects a conical aperture, and at the same time compresses its sides as far as they admit. A small quantity of sharp broken material is thrown in, and rammed to the height intended for the bottom of the pillar, which is then inserted, and more broken material thrown in, and rammed until the space is filled; see fig. 1. The pillar then, by aid of the notches on the ribs and flanch A at the surface, has firm hold of the conical mass of broken metal, and if it could sink must sink perpendicularly. Now it is evident that more force will be excited in compressing the soil than is equal to any weight which can come upon it at one time; and the surface to be supported being smooth and clean, the motion of the weight will have but little more effect than so much dead weight.

A series of pillars is then fixed in this manner, the ordinary distance of which is ten feet; these vary in height according to the undulation of the ground, within certain limits, their upper extremities being parallel to the intended plane.* This arrangement avoids a great expense in embankments, bridges, culverts, drains, as will be shown hereafter. In a cleft on these pillars are laid reverse wedges, a a, figs. 1 and 2; on which a line of bearers, either of wood or metal, are laid; the upper surface of which then forms a road for the passage of the wheels.

The wheels are two in number, the one placed before the other; the carriage has two receptacles for goods, which are suspended one on each side, the centre of gravity being always *below the surface of the rail.* The rods by which the loads are suspended are inflexible; and hence, although the weights on each side be not equal, they are always in equilibrio, because they assume such an angle as to place the distances of the centres of gravity of the two weights, from a perpendicular drawn from the point of support (the surface of the rail) inversely as the weights. To those who are unacquainted with geometry, the loads at first sight appear to require balancing; it may not therefore be improper to refer to similar circumstances as observed in the loading of a ship. If she be unequally loaded, she assumes such an angle with the surface of the water as still to sustain the equilibrium, and although it is preferable to distribute the load equally on both sides, an exact adjustment is unnecessary.

---

* Of course the method of fixing the pillars will sometimes vary with the nature of the ground. In passing through a stone country, and where cast iron is expensive, a small stone wall two feet high on the level will frequently answer the purpose.

A perfect and adjustable plane being thus obtained, no farther preparation is requisite for the moving power than an ordinary towing path. The horse is connected by a towing rope to the carriages, and proceeds on one side of the elevated rail ; and as his height will vary with the undulations, he will sometimes be below the rail, and is consequently provided with a length of rope which will enable him to vary his height without much altering the angle of draught.

The advantages to be derived from such a disposition are, that we are enabled to construct, in many cases with precision, that plane which is most effectual, and where the shape of the country would occasion too great an expenditure on the former plans. It is unencumbered with extraneous substances, and is retained in perfect adjustment at a trifling expense. It is not interrupted by snow, as a brush preceding the first carriage in a train will clear all that can lie upon the rail, and the receptacles are too far from the ground to find any impediments there. The arrangement also enables us to continue a conveyance by other means with very little interruption, as it is evident that the receptacles may be received from the one, and lodged on to another kind of carriage or vessel separately from the wheels and frame work, without displacing the goods. The receptacles being suspended, their weight preserves their position, and the articles conveyed are therefore not liable to fracture. *A vessel of water may be conveyed without losing a part.* It may be constructed on the side of a public road without occupying more space than can usually be afforded, and its effect need not be diminished by the dust, &c. from the road, as is seen on others. It may be erected on waste and irregular margins of rivers, which on account of the number of culverts and bridges usually required has hitherto been too expensive. From the removal of a great portion of resistance, the effect which can be produced upon it is greater than has before been performed, as seen in the table. The original cost, in those cases for which it is adapted, and where it offers most advantages, will be much inferior to the ordinary plan: in fact, it enables us to obtain a more direct line, and approach nearer the best inclination at a less cost than has before been done, and retain the same in repair at a much cheaper rate. It occupies less land, and is less objectionable to land proprietors. The motion may be impelled by steam, either as a locomotive or stationary power, and well admits of expeditious conveyance with perfect safety.

Having now described the general arrangements, and pointed out the principal advantages which such a disposition presents, I will proceed to describe the details of the construction and application under different circumstances.

In Plate 2, Fig. 1, is a section of the railway, with an end view of a carriage. Fig. 2 an elevation, and Fig. 3 a plan of the same. (The same letters refer to the same parts in the different figures.) A is an upright pillar; *a a*, the adjusting wedges on which the bearer B is laid. The bearers shown in the drawing are of wood, being three-inch deal planks set on their edges, and each extending over two distances of pillars; their upper surface is defended by cast or wrought iron plates.

When the rail has been some time in use, so that all has taken the proper bearing and adjusted, the rail is bolted to the pillars.

DD are the wheels, E E the arms, or axles trussed by the yoke or fulcrum F and strap G. H H are the receptacles for goods, which are here represented to be of plate iron, and are suspended to the arms by the rods I I I I. To one of the arms a chain K is hooked, and passes through a loop on the end of the box at K, to which a towing rope may be connected. Any number of carriages may then be attached together by chains hooked on to the axles.

This description applies to a carriage of the simplest form, but it is evident the principle admits of great variety according to the nature of the material to be conveyed ; all the principle requires is the position of the centre of gravity in relation to the surface of the rail, and that the parts which connect the weights be not flexible.

If one of the receptacles be empty, while the other is full, it is manifest the equilibrium will be destroyed, and the heavy side will come in contact with one of the pillars. Suppose, however, the whole weight to turn upon a point at the surface of the rail, it is evident that a certain difference of load on each side may be applied without either touching the pillar; but the weight does not turn on a point, because the surface on which it rests is at least four inches in breadth, and a greater difference of load may be admitted without any inconvenience: the question therefore is, Whether the difference of load which the principle admits of, be sufficient for practice without inconvenience? The proportions of the parts may be so varied, as to allow of almost any difference; but the proportion represented admits a difference of four hundred weight; and this is much greater than ordinary circumstances require.

Suppose the top of the rail to be flat, if there be unequal loads, the wheels will press harder on one side than on the other. To prevent this, two expedients have been resorted to, the choice of which will be determined by circumstances. The first is to shape the surface of the rail to a slight curvature forming a segment of a circle, about one-sixteenth of an inch in height being sufficient, and shaping the rim of the wheel to correspond with it. A difference of load then alters the angle of the wheels, but, on account of sufficient width being provided in the wheel, it still bears *equally and vertically* on the rail. As the curvature in the rail induces some resistance, although very trifling, I erected one having a flat rail, with the carriage so constructed, that, with a difference of load, the equilibrium might be preserved on the same principle, by the alteration of the angle, *while the position of the wheels remained vertical.* It being necessary that the wheels have flanches to keep them on the rail, the smallest imperfections either in the rails or the wheels, occasioned a rubbing of them against the sides of the rail, and a much greater resistance than the slight curvature in the first expedient; and, therefore, the first is preferable. It may be objected by some, that part of the force is lost by its not being applied to the centre of the carriage. No doubt some is lost; but the difference of the resistance of a loaded carriage, whose weight exceeds two tons, when it is drawn from the centre, or from its extreme side, does not exceed half a pound.

The circumstance of a horse drawing from a distance, may also, by some, be regarded as objectionable. Undoubtedly it is so at acute bends of the line of railway, but these ought never to be admitted; but provided the horse pull in the direction of the motion of the carriages, his distance is favourable. This is well proved in the towing of vessels on canals. The motion of a horse being irregular, there being a variation with each step, he would produce comparatively small effect, if it were possible to connect him close to and in front of the vessel. The length and weight of the rope then forms an elastic medium.

I will now proceed to explain the application of the scheme to practical use.

OF LOADING.

As the two receptacles may not be loaded at the same time, that which is to be loaded first must be supported until the second is full. Where there is a permanent loading place, the carriage may be brought over a step or block; but when it is to be loaded promiscuously, it is provided with a support connected to it, which is turned up when not in use. From the small height of the carriage, the loading of those articles which are done by hand becomes much less laborious.

OF UNLOADING.

The unloading may be done in various ways. One method is shown in Plate 2, and supposes the substance to be coal which is to be discharged into a barge. Figure 4 represents a side view, with a section of part of the shoot and side of the wharf. Fig. 5 is a front view of the same. O, is the shoot, or sloping trough, which receives the coal from the carriage, and conveys it to a barge brought underneath. A, A, Fig. 4, is part of the line of railway brought to the wharf. P, is the last pillar of the line. B, is a rail which turns vertically on a joint on P. Q, is a foot or stop to limit the angle which the rail may assume, by its coming in contact with the shoot. When the rail is in a horizontal position, a carriage may be brought upon it, but there is a projection about the centre of the under side of each box, which, coming in contact with the bar R, Fig. 5, is prevented from proceeding too far. There is also a projecting arm on the end of the rail at S, Fig. 4, which is curved to correspond with the circle of the wheel, so that when the carriage is ready to be discharged, the face of the front wheel coincides with it, and cannot go beyond it. The centre of the carriage being then over the bar R, the rail may be elevated to the required angle, and the suspending rods will remain perpendicular, as shown in the plate. The ends of the boxes being made to open by turning on a joint at the upper side, as seen in Fig. 2, and being secured only by the latch, as at H, Fig. 1, when the carriage is brought to the inclined position, one end of each latch has touched a projection on the shoot which turns them up; the weight of the coals in the boxes then forces the ends open, and both are discharged at the same time; *the attendant has therefore only one motion to perform,* viz. changing the position of the rail, the unlatching and discharging being consequences of the altered position.

The carriage then resumes its horizontal position, and is directed on a siding or branch to make room for another.

When it is intended to unload at various and undetermined parts of the line, the boxes are suspended by their extremities, and turn upon their own centre, so that they discharge sideways.

For some purposes, it may be convenient to open the receptacles at bottom.

BRANCHES,

Turning at Right Angles.

This is done on the same principle as is adopted on other railways, but arranged to accommodate the present plan. Instead of bringing a carriage on to a circular plate turning on a centre, these are brought, one or two at a time, on to a rail which turns upon its centre. In Figs. 6 and 7, *b b*, *c c*, represent parts of a continued line, and *d d* the branch into which a carriage is to be transferred. The intermediate or swinging rail turns on the pillar T, and having a carriage upon it, can be directed to *d*, the branch.

Branches in General.

In cases where two lines must communicate without interruption, or loss of time, a jointed or moveable rail is applied, which will direct to either of two lines. In Fig. 9, *k i*, *m n* are parts of the general line, and *o p* a part of a branch; *i o,* is the joint rail, which turning on the centre, *i,* may be directed to *o,* or *m.*

Passings.

When a line is not provided for each direction, passing-places, as on the usual plan, are necessary. Fig. 8, *e e,* is a part of a continued line, *i h,* a side branch. Upon *f* and *f,* as centres, there is a joint rail, which may be directed to *g* or *h* as required, and carriages coming upon *g g* may be passed by others proceeding along *f i h f.* It is of course advisable that the empty carriages turn out if one of the trains be so.

Crossing Roads.

The expedient necessary in these cases will depend on circumstances; and in arranging the line it will be necessary to choose such places as are best adapted. If the road can conveveniently be crossed where it is in deep cutting, or where its surface is sufficiently below the height of the rails, the same, by having a proper span, may pass over the road without interrupting the traffic. If the difference of height be insufficient, other means must be resorted to. If the road to be crossed be a private one, or one on which there is not much traffic, the railway may be made to open at that place by a gate, as at U in Fig. 7, or by a double gate swinging on a pillar in the centre of the road. If a free passage on the road be always required, the gate will generally stand open, and when a train of waggons on the railway is approaching it, the driver will step forward and shut the gate, and afterwards re-open it, or the last carriage may be made to unlatch the gate, which may be so hung as to fall open, without trusting to the driver. If the road be crossed near the position of a turnpike or parish gate, the same may be made to answer the two purposes.

When no such gate can be admitted, as on public roads with considerable traffic, a small bridge may be built over the railway; and in such a case it will always be desirable to cross where the *public road is above the line of railway*, to avoid raising the road.

Occupation passings, for private convenience, are accomplished by merely constructing a rail at any required place, in such a manner as to allow it to be lifted up upon one end as a centre.

Crossing Rivers, Rivulets, and other Water-courses.

If a stream be at all times fordable, no other arrangement will be necessary than an increased span at that place. If not fordable, and the stream be small, or if a drain, the railway will continue on the same construction; only a platform or small bridge, *sufficient only for the weight of the horse*, must be constructed, but that may be in all cases much lower than the surface of railway, and therefore much shorter than a bridge having the same level.

In crossing a large river, the construction of railway will vary. If a bridge already exist near the spot, advantage may be taken of it as circumstances admit.

1*st*. In some cases the railway may be constructed upon and on one side of the existing bridge. 2*dly*. It may be separate, and near the bridge, that the horse may pass over it. 3*dly*. The parapet wall or ballustrade of an existing bridge may become the railway. When an entire new passage is requisite, a bridge must be constructed; but the principle enables that to be accomplished at a much less expense than is necessary in general,

That part of the bridge which is usually the ballustrade, now in fact becomes the bridge for the load; a slight platform being all that is necessary for the weight of the horse. The motion being uniform, and producing little more effect on the bridge than dead weight, less strength is requisite on that account. The frontispiece exhibits one design for the passing of a river. It is partly supported by struts, and partly by wrought iron suspending bars, which extend from the abutment to the end of an inverted king-post in the centre. When height is not required for navigation, this becomes a very economical construction. A suspension bridge also very well applies for this purpose ; the horizontal line having its bearing upon the curve by means of cast-iron framing.

Junctions with Navigations, Roads, and Railways of other kinds.

The facilities which are offered by the new principle in effecting this operation, constitute one of the leading advantages to be derived from it. As any part of the railway itself may be made moveable, and separable from the rest at pleasure, the same may virtually constitute part of a crane. First, then, let us suppose the railway to unite with a navigation. If the article conveyed admits of being shot out of the carriage to a vessel, the method is already explained under the head of unloading. But if it does not, a terminating rail projecting over the side of a wharf, &c. having received a carriage upon it, may be lowered to any required depth; and the receptacles containing the goods may be released from the wheels and their frame, and being deposited side by side, the wheels may be transferred on to a branch until they are again required. It is obvious many things will not require a complete box having four sides to retain them. Bricks, for example, will only require a platform; slate, a platform and a rail a little above it. Goods which are in cases, crates, &c. will not always require even a platform, as they may at once be suspended from the slings. Suppose the two opposite slings to be continued as low down as the place of the bottom of the receptacles, and connected there by a cross bar, having a roller upon it; it is evident a moveable platform may be laid upon two of these, and when the whole carriage is lowered into a vessel, the platform may be rolled off, if necessary, and the goods deposited in the required position. It would be tedious to enter into a detailed description of the arrangements which may be required for all purposes; it is sufficient to give the general principles, and I trust the above explanation is quite satisfactory.

Secondly; The methods of uniting this principle with roads and railways of other kinds, are generally as follows: The transfer must take place where the road is so much lower than the railway, that a truck may be rolled under the suspended boxes; if not, the rail at which the transfer is to be made must be moveable, and raised as occasion requires. Suppose the moveable rail to be supported and moveable upon two or more parallel joints or arms, after the manner of a parallel ruler, it is manifest that if a carriage be upon it, the same may be raised by rack and pinion, or small crane or jack, conveniently to the required height. If then the truck be brought under the receptacle, it may almost instantaneously be released from the sling, and deposited on that truck.

By a truck, I am supposing a carriage of any description without what is termed the body, it being simply the wheels and frame which connects them.

By this means a railway may be brought near to a town, and the conveyance continued to any part thereof with very little loss of time.

Description of the Frontispiece.

The frontispiece exhibits a portion of railway in use, and the methods of overcoming the several obstacles that most frequently occur. On the left is seen the jointed rail or gate used for crossing private roads. Near this, and on the right of it, is the crossing a fordable stream; the line then proceeds over slightly undulated ground till it meets with a river, the bridge over which is adapted particularly for this purpose. The next peculiarity is a turning rail, by which the waggons are transferred, two at one time, on to a branch at right angles. The

branch is seen constructed parallel to a public road, to which it constitutes a fence. The line then passes under the public road, and is ultimately seen skirting a hill side, without requiring the usual necessary side-cutting.

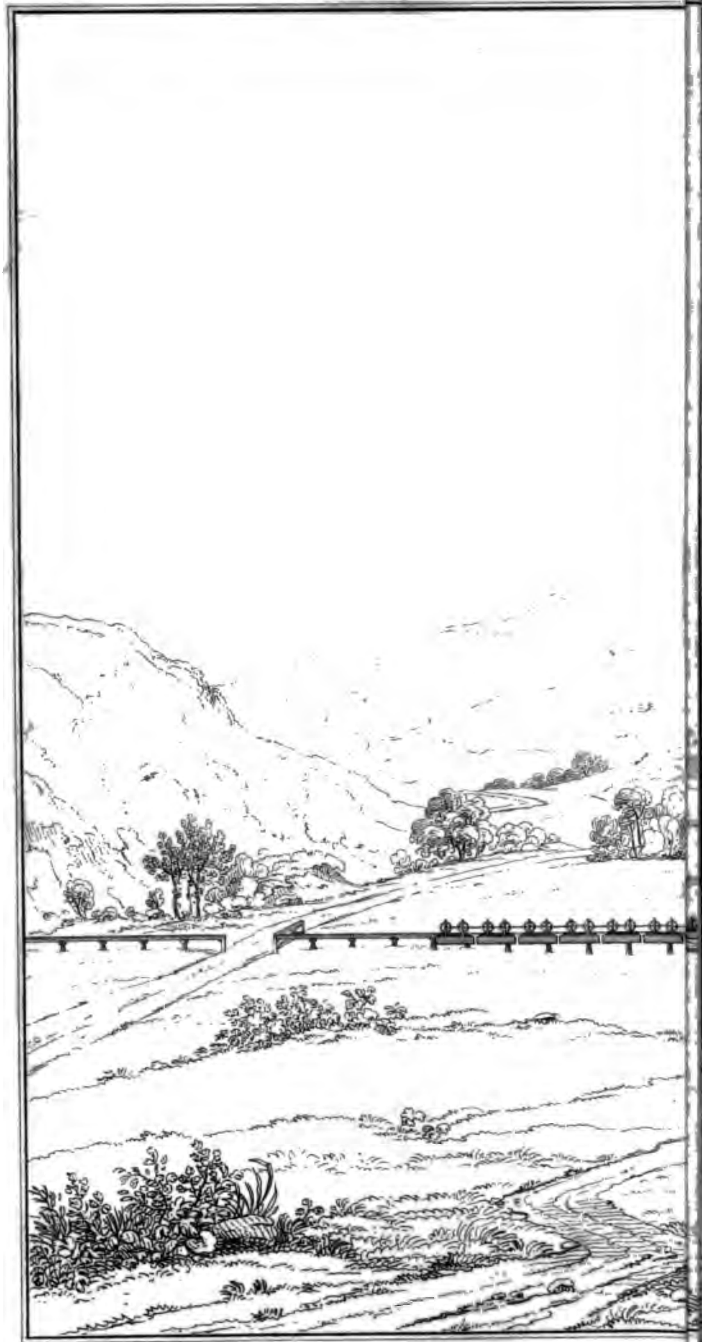
THE END.

LONDON:
PRINTED BY J. MOYES, GREVILLE STREET.

branch is seen constructed parallel to a public road, to which it constitutes a fence. The line then passes under the public road, and is ultimately seen skirting a hill side, without requiring the usual necessary side-cutting.

THE END.

LONDON:
PRINTED BY J. MOYES, GREVILLE STREET.



H.y Palmer del.

DESCRIPTION
OF A
RAILWAY ON A NEW PRINCIPLE;
WITH
OBSERVATIONS ON THOSE HITHERTO CONSTRUCTED.
AND
A TABLE,
SHEWING THE COMPARATIVE AMOUNT OF RESISTANCE ON SEVERAL NOW IN USE.
ALSO
AN ILLUSTRATION OF A NEWLY OBSERVED FACT RELATING TO THE FRICTION OF AXLES,
AND A DESCRIPTION OF
AN IMPROVED DYNAMOMETER,
FOR ASCERTAINING THE RESISTANCE OF FLOATING VESSELS AND CARRIAGES MOVING ON ROADS AND RAILWAYS.

BY
HENRY R. PALMER, CIVIL ENGINEER,
Member of the Institution of Civil Engineers.

WITH PLATES.

I*Wallen

SECOND EDITION, REVISED.

LONDON:
PRINTED FOR J. TAYLOR,
AT THE ARCHITECTURAL LIBRARY, HIGH HOLBORN.
1824.

LONDON:
PRINTED BY JOHN HILL, PATERNOSTER ROW.

CONTENTS.

Page

General Remarks 1

Observations on Railways 6

Illustration of a newly observed fact relating to the friction of axles.. 21

Description of an improved Dynamometer 26

Table of resistance on several Railways 29

Description of a Railway on a new principle 33

Outline of the principle 34

Advantages to be derived from such an arrangement 41

Details 43

Of loading 48

Of unloading .... *ib.*

Branches, and communicating therewith 51

Passings .... *ib.*

Branches in general 52

Crossing roads .... *ib.*

Crossing rivers, and other water courses 54

Junctions with other means of conveyance 56

Description of the Frontispiece 57

PREFACE.

In submitting to the public a method of conveyance differing altogether in principle from any that has before been constructed, I am not unconscious of the difficulties to which prejudice will expose me. But having submitted my plan to such tests as were satisfactory to many of the most eminent Engineers and men of science, I am encouraged by their opinion, and by my own conviction deduced from extensive observations on similar works, to publish a description of it; and that the nature and peculiarities of my plan may the better be understood, I have introduced some remarks on the methods now generally used.

Obstacles to the adoption of the new method may occur, which may not appear to be provided for; but, I trust, a little reflection will evince the impossibility of illustrating all variety of cases, without rendering the description too long and tedious. The principle, I am confident, admits of very extensive application, yet I would not have it thought that I advise it for every situation, or with the presumption of entirely superseding all former methods.

In some situations my plan will be productive of considerable advantages, while in others it would be inferior to the ordinary construction. The nature of the country, and purposes required, can alone decide the preference.

Very little has been written on the subject of railways, and I know of no work which treats of the several kinds comparatively, or points out the difference of resistance upon them. Such experiments as have been published, are too indefinite for practical purposes. They have simply stated the effect which a horse has produced in each case, without either describing the construction of the railway or its inclination with sufficient precision. There is not only a great inequality in the strength of different horses; but the same horse being capable of producing a much greater effect during a short time, than he can continue day after day successively, the exertion of a horse is not, therefore, an useful standard, more especially in the absence of other particulars of equal importance. The table which is hereafter given therefore refers only to some of those railways which have come under my own observation; and although it does not exhibit a comparison of the original effect which might have been produced upon them when new, or the comparative value of their original construction, it describes them in their present state, and points out the importance of a strict attention to the construction and condition of all such works.

13, *Abingdon Street, Westminster,*
1824.

Note.—A working model of my Railway may be seen at Mr. Smart's, New Road, near Westminster Bridge.

GENERAL REMARKS.

THE importance of inland communication is so generally acknowledged, that no arguments need be adduced in favour of an attempt to promote it; every individual is either directly or remotely interested in its improvement.

There are but few articles of the first necessity whose nominal value is not greatly dependent on facility of conveyance; and this remark applies still more to the numerous articles of luxury which, introduced at first by the prodigious wealth and the high degree of refinement this country has attained, are now by habit rendered indispensable. The various improvements in our manufactures would have been much less valuable, (and, in some cases, even useless,) had not the means of conveyance received a proportionate advancement; the charge of carrying the raw material to the manufacturing district, and the manufactured article to the market, forming no small proportion of its price to the consumer. To the same improvement may also be attributed the increased use of the various minerals and metals which might otherwise, for the most part, have remained in their natural strata.

Of the several methods of conveyance, navigation has been preferred as the most economical; and where natural rivers have not existed, or where they have not been applicable to the puposes of conveyance, artificial canals have been executed, and that already to a considerable extent. But amongst the variety of localities which the surface of the country presents, there are many in which canals are impracticable or too expensive; and in such cases Railways have been adopted, but at the same time with a conviction, that the effect which could be produced upon them would be inferior to that on which they were intended as a substitute; and therefore the natural peculiarities of the surface have determined, in a great degree, the comparative advantages of certain districts in regard to conveyance. But canals themselves have not yet yielded advantages to that amount which, at first thought, they appeared to hold out. They cannot directly communicate with every town, or individual property, for whose use they are intended; and branch lines of communication, on some other principles, become indispensable. The distance and other localities of the several positions referred to, together with the expense of transhipping from one kind of conveyance to the other, necessarily precludes them from deriving the full benefit of those works.

Railways have been frequently recommended, and adopted as branches to canals; but the nature of them is such as to require certain localities in the situation to render their application profitable. When the trade has to ascend over an inclination exceeding certain limits, they offer but little advantage over a common road; but, on the contrary, where the trade has to descend, and that at a certain inclination, the effect on a well-constructed railway is considerable, and it becomes a profitable undertaking. But in the use of railways to general purposes, the inconvenience arising from transhipping is still observed, as in the case of canals, although in a less degree; as a great proportion of the traffic must be ultimately conveyed to its destiny from the main line, communicating by means of the common road; and thus, although a district may have the advantage of a canal, and a situation not very distant from the canal be possessed of a branch line of railway, the dispersion of the traffic must ultimately take place by means of the common road, and thus the goods conveyed between the extreme points may undergo four loadings and unloadings before they arrive at the place of their consignment. They must first be conveyed to the canal, perhaps by the common road; from the canal they are transferred to the railway; and having proceeded as far as its direction is useful, are again transferred to the road.

The delay and expense of these several changes may more than compensate for the advantages which canals and railways hold out over common roads, unless the distance exceed certain limits; and, hence, goods are frequently conveyed six or seven miles by the public road in preference to a canal.

The connexion of the several means of conveyance with each other is, therefore, a very important branch of the subject; and if this were rendered less obstructive, canals would be considerably benefitted, and railways much more encouraged.

Notwithstanding the obvious importance of railways, both for public and private purposes, it would seem that an acquaintance with the nature of them is much less general than might have been expected, as their useful effects have been so variously estimated. I shall, therefore, offer some remarks upon them previous to entering upon the description of my new method of conveyance, which classes in their denomination.

OBSERVATIONS ON RAILWAYS.

The first principle in which a railway excels a public road, is in the arrangement of the plane intended for the surface; the second in the surface itself, as being more hard and smooth.

Railways are constructed in various forms as respects the dimensions and shapes of their parts; the parts are also connected in several ways; but they may be distinguished generally into two kinds. The one, and that first used, is called a Tram Road, the plates of which are usually flat and about four inches in breadth, having a flanch on the inner side to direct the motion of the wheels. The wheels of the carriage are narrow on the rim, the breadth being diminished as far as the strength of the material will justify. The second kind are called Edge rails. These are of less width than the former, being usually from one inch to two inches and a quarter in width. They project a little above the surface of the ground, and, on that account, are less liable to dirt, &c. lying upon them. They have no flanch to direct the wheel; their surface is either flat, or a little convex. When flat, the wheels are provided with a flanch which directs their motion; if curved, the wheel is formed with a groove, corresponding nearly to the curvature of the rail, and therefore no distinct flanch is necessary.

The rails are made of various lengths; if composed of cast iron, that most common is three feet, some extend to six feet; if of malleable iron, from ten to twenty feet. The rails are connected together upon a sleeper or block at each joint. The sleepers for the short rails reach from two opposite joints, and are generally of wood, which then constitutes the foundation. The blocks are pieces of stone, about sixteen to eighteen inches square, sometimes more, depending on the weight of each loaded carriage; the two opposite of these are sometimes connected together by a cross sleeper of iron, but the two lines of rail are more frequently independent of each other.

Railways are either level or inclined, as circumstances require, provided the nature of the country admits of a choice. When the trade is great or nearly equal in both directions, as may be expected in public lines, the railway is, if possible, made level: where the trade is all in one direction, and that downwards, as from a mine to a port, the line is made inclined, and, if possible, the inclination is such that the resistance of the loaded carriage downwards is equal to that of the empty carriage returning upwards. The effect which can be produced on a railway is estimated by the quantity of weight which a given power can draw upon a level surface of it; the resistance then being only such as arises from imperfection of the parts, and the friction of the axles of the carriages; any additional resistance occasioned by an ascent or inclination being only a subject of calculation. But as the force required to draw any weight up a given inclination is in proportion to the weight itself, it follows that the angle of inclination will be in proportion to the resistance of surfaces, and the proportion of the carriages to their load.

And, in the case of an inclined railway whose traffic is all in one direction, it will be comparatively of small importance to reduce the resistance of surfaces, in order that a given power may convey a greater load downwards, if the same be not equal to return upwards with the empty carriages. In like manner, in proportion to the quality of surface obtained, a regularity of line must be observed. As every bend occasions considerable resistance, and that in proportion to the weight conveyed, a given power may be capable of drawing a considerable weight along a straight line, but may be incapable of continuing the same effect through a bend or curve.

The great difference in effect produced by the different railways, results not only from the peculiarity of their parts, but also from the difference in the arrangement of the lines in respect to their inclination and regularity, and the consequence of a trifling difference in these is much greater than is usually supposed.

The natural irregularities of the country, the interception of the line by water-courses, the imperfections of soil, and positions of private property, constitute the principal obstacles in the way of adopting that line which would be most profitable. The natural impediments are of course only to be surmounted by the skill of the projector; but with a view to the saving in the first cost of the work, the result is sometimes nearly defeated. But the position of private property is usually the greatest of these obstacles. Lines of communication often suffer much diminution of effect, even at the expense of overcoming some natural obstacle, simply to avoid an alteration in the shape of some pasture. An intrepid determination to yield neither to the right or left where an obstacle presents itself, cannot be approved of; but that mistaken economy which gives way to every trifling impediment should be jealously avoided.

Railways differ essentially from canals, inasmuch as the effect which can be produced upon them bears a strict relation to the quality of their execution. On a canal the resistance of the fluid is nearly all that has to be overcome, and that with a small velocity is comparatively trifling, let the workmanship of the canal be what it may. But on railways, the whole resistance on a level line, except the friction of the axles, arises from *imperfections which are not essential to the principle:* if, therefore, the best possible line be chosen, much remains to be encountered.

It is, perhaps, too common an error which attributes the advantages of railways over common roads to be derived from the material employed. It is safe to infer that such a notion is not uncommon, when we observe an almost total neglect of the adjustment of the rails, and of the construction of the carriages. I have seen one railway, or rather a tram road, having a fall of a quarter of an inch to a yard, down which it required the full exertion of a horse to draw one ton and a half, where, with the same materials properly disposed, the carriage would have descended by its own weight. The railway referred to cost as much originally as one on which the same power might have produced five times the effect.

If a plane be perfectly hard, smooth, level, and straight, and the wheels of the carriage perfectly hard, smooth, and cylindrical, the motion of such carriage would be impeded only by the resistance occasioned by the friction of the axles. It is therefore necessary, in the construction of railways, to ascertain distinctly those circumstances which together make up the great resistance seen in practice. By a reduction of these, we are not only benefitted by a saving in the cost of draft, but by a proportional diminution in the expense of repairs; *because these works are rather destroyed by their own imperfection, than by the operations for which they are intended.*

A railway and its carriage form together one machine; it is only from the extent of one of its parts that they are separate in idea, and no excellence in the one will compensate for an imperfection in the other. The parts of the plane, and those of the carriage, are therefore each of an equal importance, and must invariably be considered in relation to each other. The improvements are not to be obtained from a perfection in any one part, while the others are neglected, but from a due attention to the construction and proportion of all.

With a view to economy in the quantity of materials, the load is divided into a number of parts, and distributed amongst so many carriages; therefore, the power that gives the motion is necessarily at a great distance from some of the carriages, and if the line be irregular, the power will not be exerted in the direction of the motion of the carriages: their motion will consequently be partly directed by the reaction of the flanches on the sides of the rails, and the amount of that reaction is deducted from the effect which the power might otherwise produce; and as much power as is equal to that reaction is exerted to displace the position of the rails. But it is not enough that the general arrangement of the line be as free as possible from bends; if the parts themselves do not nicely correspond to it, a resistance is encountered which is not necessary in principle. Some arrangement is always necessary to preserve the direction of the carriages. On tram ways, the flanches on the plates serve that purpose; on flat edged railways, flanches on the wheels are necessary; and the smallest imperfection in the rails will occasion a cóntinual rubbing of the one against the other, *making a resistance greater than that of the imperfection of surfaces*, and every such action tends to disturb or loosen the rails, and the foundation on which they stand.

In tram roads, the rims of the wheels are generally so far out of proportion to the strength of the materials, that, by successive motion, they form a rut or groove in the plates, and ultimately divide them longitudinally into two parts. The object of the small width is principally to pass the obstructions lying upon the rails the more easily. When any such irregularity is once found, the wheels, from other imperfections in the works, do not follow uninterruptedly the courses of those ruts, but are fequently escaping upon the sides of them, and, returning again, act with a violence on the rails, which tends to disturb their position, and produce frequent fracture. In edge rails, the proportion of bearing surface to the weight is frequently too much neglected, and an irregularity is given to the motion, which becomes a resistance, and destroys the parts.

If one general plane be more effectual than another, the parts of it are of like importance. A perfect equality in the stability of every block which supports the line cannot be expected› and, although the weakest may be capable of resisting a dead weight equal to that which may pass over it; the irregularity, or jolting motion arising from the several imperfections, constitutes a force whose effect on the foundation is soon observed. The surface of the rails being near the ground they are necessarily exposed to dirt, and other extraneous substances lying upon them. This evil is most evident in tram ways, and although inferior on edge rails, those are not entirely free from it, especially when the articles conveyed are at all adhesive in their nature, that, by falling from the waggons, distribute the obstruction on the rails as they proceed. The presence of extraneous substances on the surface of the rails is then not only an obstruction to the motion, but its effect has a continual tendency to destroy the perfection of the plane, and occasion repeated and expensive repairs. The smallest protuberance on the surface, if it be sufficient to change the direction of the motion, is an impediment.

I made an experiment on a branch of the Cheltenham tram road (which was nearly new, and in good condition), with a view to ascertain the difference of resistance occasioned by *dust* lying upon the rails. The carriage and its load weighed five thousand two hundred and sixty-four pounds: the rails being swept clean, the resistance was thirty-six pounds; the rails being slightly covered with dust, the resistance was forty-three pounds. Consequently, the difference of resistance to that weight was seven pounds, being upwards of one-fifth increase.

On the edge railway at the Penrhyn slate quarries, whose rails are convex on the surface, it is usual to carry a butt of water before the train of carriages, which sprinkles the rails in its progress, and washes their surfaces. This railway is upon an inclination of three-eighths of an inch to a yard. The train consists of as many carriages as three horses can convey. The power required to draw up the water carriage, at a mean weight, is twenty-one pounds, being seven pounds to each horse; which should be at least equal to the quantity of resistance occasioned by the dust, if the expedient be economical. The same practice is not uncommon on tram ways, but those require it in a greater degree *.

But the Cheltenham experiment which has been referred to, is not to be taken even as an average of those frequently seen in practice. On the main line of the Cheltenham railway, which is on the side of a public

---

* The practice of carrying water in front of the train, was suggested by the diminution of resistance perceived during rain. On some tram ways, an additional waggon is attached to a horse during rainy weather.

road, the superfluous obstacles were considerably greater. The same horse may draw upwards of one ton more on the branch on which the experiment was made than he does in practice on the general line.

Since the several imperfections to which the surfaces of railways are exposed continually derange the position of the foundations, and render the line irregular, destroy the parallelism of the two lines of rails, and ultimately induce repeated fractures and expensive repairs, the adjustment of the rails to their proper position becomes an expensive operation, if strictly adhered to.

But the adjustment of railways, as hitherto constructed, is in fact a rebedding of their foundation, and does not admit of that accuracy which perfection desires. If the adjustments of a mill were dependant on similar circumstances for their truth, the motions would soon destroy its parts; the difference in the two cases consists almost entirely in the degrees of complication, but the effect is more strikingly manifest in the one than in the other. Where a careful attention has been paid to retain or correct the position of the parts as they may from time to time have been deranged, the expense attending it, even with the present means, has been amply compensated by the saving in carriage and damage to the works. How much advantage then would be derived from the adoption of some method by which the adjustment might be accomplished with precision, without disturbing the foundation and the rails.

Railways being an improvement on common roads, their superiority was so decisive in regard to economy of draught, that the carriages, at least by far the greater number of them, have been neglected, as if they contributed but little to the resistance. The wheels are applied to use immediately from the foundry, without even being made circular. The axles, the friction of which constitutes a large proportion of the resistance, are most generally of a very inferior kind. When we refer to the great difference of results obtained by different experimenters on the friction of axles, although in every case of such experiments the best materials and workmanship have been employed, it necessarily follows, that a slight difference in circumstances may produce considerable variation in effect*.

Being frequently in the habit of measuring the resistance of a carriage on the construction hereafter described, I observed a circumstance which subsequently contributed to some new light on this part of our subject; and, as it relates equally to many other objects in practical mechanism, the observations are stated at length.

---

* I have been recently favored with an experiment made at Myrthyr Tidvil iron works, with a view to ascertain the difference in resistance between a railway carriage or tram, whose axles were rendered smooth by turning, and one whose axles were simply forged. The results were as follows :

	lbs.
The resistance of a full waggon, weighing 3720 lbs. having turned axletrees, was . .	60
Ditto, having axles unturned	110
Difference	50

During a succession of experiments, occasionally for many months, I invariably perceived, that when fresh oil was applied to the axles of the carriage, *the resistance was increased*, and it required the ordinary motion of the carriage for several days to restore the resistance to its usual standard. No other presumption occurred to account for this fact, than the possibility of the oil being better adapted for its office after being some time exposed to use. It was suggested by a scientific acquaintance, that the oil became thickened, or less fluid, after exposure to the air, and was therefore better able to resist the contact of surfaces. In order to prove this, I thickened some oil artificially, by the admixture of a small quantity of bees' wax. But the appearances were the same as before. It then occurred to me that there was not sufficient play, or difference of diameters, between the axle and the nave in which it worked; I therefore had the axles slightly reduced. On again measuring the resistance, the circumstances were found as before, but differing in amount, the resistance being slightly increased. I was by this time convinced that the quantity rather than quality of oil occasioned the appearances; to prove which the axles were made perfectly clean, and then simply moistened with oil by the finger, previous to inserting them in the wheel. In this state the resistance was again measured, and found to be *similar to the standard usually observed after the carriage had been some days in motion as before described.* It being then proved that the *quantity* of oil occasioned the difference of resistance, the following solution of the manner in which the superfluous quantity could produce such an effect, appeared reasonable:

Fig. 1.

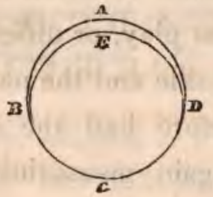
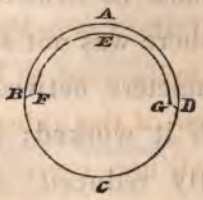


Fig. 2.



Let A, B, C, D, Fig. 1. represent the circle of the hole in the nave of the wheel, and E, C, the section of the axle. The circle E, C, touches A, B, C, D, only in the point C. A very acute angular space then remains between A, E, and C, on either side of E, C. If that space be filled with oil, the oil may be considered as a wedge, and if the outer circle be set in motion, that wedge will endeavour to pass the point C. But it cannot pass in its present form without raising the circle E, C; and E, C, having the weight of the carriage upon it, would resist its passage.

Now this continual and unsuccessful endeavour to pass the point C, will occasion an impediment to the motion.

To put this solution to the test, the axles were formed as in Figure 2. A, B, C, D, is the hole in the nave as before, and E, F, C, G, the section of the axle. The lower semicircle of the axle here corresponds with, or is parallel to the outer circle, but no farther, because, *if it corresponded throughout the circle, the axle would* *be liable to jamb, as other experiments have proved.* The coincidence then ceases abruptly, as at B, F, G, D, and the space above, which contains the oil, is not angular, but the quantity of oil which is to pass toward the lower semicircle, is determined at B or D.

On measuring the resistance with the axle thus formed, I found it not increased by any quantity of oil that might be inserted, but by dispensing with the angular space and consequent wedge-like action of the oil, *the resistance was one-tenth less than the former standard.* In cases wherein the difference of diameters is considerable, it is not to be apprehended that the obstruction from the quantity of oil would be of consequence: but it is desirable to make the bearing surfaces nearly to correspond, to obtain a greater *width* of touching surface, and to govern the motion more perfectly. The form of axle just described is in fact the converse of a well-made plummer block used in machinery.

The several kinds of resistance exist in a variety of proportions in the many railways that have been constructed, and, as with public roads and carriages, much ingenuity has been exercised on particular parts of the works, neglecting the rest. The very dissimilar results are therefore not to be ascribed to any one particular defect; but when we know how small a difference in circumstances may materially alter the amount of effect—that in each case the same number of bridges, culverts, drains, cuttings, and embankments, are required, and the same quantity of land occupied, it is often to be regretted that so much effect is lost, only from ignorance or mere negligence.

Perhaps if some accurate means of ascertaining the resistance of roads and railways were on all occasions used, their improvement would be much advanced. The real value of either being then unequivocally compared, the amount of defect could no longer be a matter of mere opinion. The proprietors would then know whether an apparent inferiority arose from a difference of horses or difference of circumstances; and it would be a great advantage to introduce a clause in contracts, which would determine the effect to be produced. The methods by which the resistance of roads and railways have been ascertained, have not been sufficiently accurate, or have been too inconvenient for general use. The dynamometers, which denote the resistance by the degree of extension given to springs attached to the carriage, are convenient as portable instruments, but do not denote the measure with the necessary precision. The resistances are not equable from the irregularities of the surface; neither does the force which draws the carriage continue equable. When horses are employed, those instruments are of no service whatever. The effect of the unequal force or resistance occasions a vibratory motion to the indicating point, and we can never have confidence in any result they exhibit. Similar defects are observable in all the instruments I have seen.

Having had frequent occasion to ascertain these resistances, I constructed an instrument which, by removing the imperfection referred to, has been completely successful. The problem was to make such an instrument as would indicate very small differences, but which would not yield *suddenly* to a change of resistance. I therefore connected to a spring dynamometer, a semicircular close copper vessel containing water; at the centre is a spindle, on which an arm or fan is fixed, and which very nearly corresponds with the inside of the vessel. The springs are so connected with the spindle, that they cannot be acted upon without the arm or fan turning upon its centre, and passing through water. In order to pass through the water, the latter must escape by its sides, and the space being extremely small, *it cannot pass rapidly, but will yield to the smallest force.*

By way of exhibiting the difference of resistance upon different railways, a table is annexed, which contains several.

The first column contains the articles conveyed; the second, the resistance in proportion to the weight; the third, the whole effect produced, *i. e.* including the weight of the carriage by one horse, or one hundred and fifty pounds, at two miles and a half per hour; the fourth, the useful effect, or the load conveyed, in pounds; the fifth, the same in ordinary measures; the sixth, the inclination, expressed by decimal fractions, on which a railway, whose resistance is equal to that specified, should be constructed, that the resistance of the loaded carriages downwards, may be equal to that of the empty carriages upwards; the seventh, the effect produced under such circumstances; the eighth, the useful effect under the same, the weight of the carriages being deducted. In each experiment, the power of the horse is assumed at one hundred and fifty pounds, moving at the rate of two miles and a half per hour.

Note.—In the inclinations, the weight of the horse itself, as part of the effect produced, is not taken into account, that the table may equally serve where mechanical force is employed. Some allowance must therefore be made where horses are used, but the difference in the inclinations given will be very trifling.

TABLE, exhibiting the amount of Resistance in a straight line upon several Railways, also showing the effect which can be produced by a force of 150 lbs. at two miles and a half per hour, being that exerted by an average good horse, through an ordinary day's work.

No. of Exper.	List of Railways.	1 Materials conveyed.	2 Resistance in proportion to the weight.	3 Effect produced on a level by a force of 150 lbs. at 2 miles and a half per hour.	4 Useful effect or weight in pounds, carriages deducted.	5 Useful effect in tons and parts. Ton cwt. lbs.	6 Proper inclination for a descending trade.	7 Effect produced on the proper inclination by 150 lbs. carriages included.	8 Useful effect on the inclination.
1	Llanelly Tram Road, S. Wales, ..	Coals.	$\frac{1}{59}$	8850	4602	2 1 10	,005958	6 1 92	3 3 38
2	Surrey Tram Road..............	Chalk.	$\frac{1}{60}$	9000	6750	3 0 30	,010000	10 0 100	7 10 75
3	Penryhn Slate Quarries, edge rail road, curved surface.........	Slate.	$\frac{1}{87}$	13050	10084	4 10 4	,007237	15 14 68	12 3 12
4	Cheltenham Tram Road	Coals.	$\frac{1}{90}$	13500	8679	3 17 55	,005263	11 9 4	7 7 27
5	New Branch of Ditto, slightly covered with dust	Do.	$\frac{1}{122}$	18300	11765	5 5 5	,003883	15 10 53	9 19 67
6	Ditto, swept clean	Do.	$\frac{1}{146}$	21900	14079	6 5 79	,003244	18 11 59	11 18 95
7	Edge Rail Roads near Newcastle upon Tyne	Do.	$\frac{1}{170}$	25500	17773	7 18 77	,003146	24 9 59	17 1 21
8	Railway invented by H. R. Palmer	Do.	$\frac{1}{300}$	45000	33750	15 1 38	,002000	50 4 52	37 13 39

Note.—I am indebted to Mr. Grimshaw of Sunderland for the data of No. 7.

It must be observed, that the proportion of real to the useful effect will vary according to the nature of the article conveyed, as on that the proportion of the weight of the carriage to its load depends.

The results due to the assumed power of a horse of course vary from the effect really produced in the ordinary practice on the several railways, on account of the difference of horses employed, and the bends in the courses of the lines. The result due to a level and straight part of Llanelly railway is, according to the table, two tons, one hundred weight, and ten pounds, but, in fact, each horse conveys only one ton and a quarter. Also the effect due to a horse on the Cheltenham railway, is three tons, seventeen hundred weight, and fifty-five pounds; but each conveys only three tons. And, on the contrary, the effect due to a horse on the edge rails near Newcastle, is seven tons, eighteen hundred weight, and seventy-seven pounds; but the horses employed there, convey eight tons eight hundred weight each, and some of them more.

The second column, exhibiting the proportion of resistance to the load by a fraction, also expresses that inclination on which a carriage would descend in a straight line (having such a resistance) without acceleration.

The proper angle upon which a railway for a descending trade should be constructed, varying with the proportion of the weight of carriages, to the loads they convey; the difference in effect in columns seven and eight, occasioned by a difference of resistance, is not so distinctly exhibited as it might have been, were the same proportion observed throughout. The calculations are deduced from the experiments as they were made, and the latter were performed on one of the carriages which might be considered as an average of the rest usually in operation on the several lines. The three experiments on the Cheltenham railway being with the same carriage, point out very distinctly the difference in effect in a descending trade, which results from apparently slight imperfections, viz. the difference of resistance occasioned by the dust alters the angle of inclination, and the angle being altered, the ultimate difference is *three tons seven hundred weight in one horse's load.*

DESCRIPTION

OF A

RAILWAY ON A NEW PRINCIPLE.

THE leading problem in our present subject to convey any given quantity of weight between two points at the least possible expense. The expense of conveyance is compounded of the original cost of the means which are employed, the cost of the repairs to which it is liable, the expense of transporting the articles or of overcoming the resistances to which their motion is exposed, and the cost of loading and unloading the same.

In some instances expedition is necessary to the value of the work; but in all, that the operations should not be exposed to interruption, either by occasional imperfections of the method employed, or by peculiarities of weather.

From what has been before advanced it must be inferred, that our first principle should rather be to remove every thing which is an impediment to the motion, rather than to submit to their existence, and search after the most effectual method of overcoming them; and therefore a line of railway should be as straight as possible; it should be nicely adjusted to that plane which is most profitable; its parts should be as few as circumstances will admit; the touching surfaces should be hard and smooth, and should not be exposed to extraneous matter lying upon or adhering to them: the parts should retain their position; and if, by accident or unavoidable circumstances, any should yield, an adjustment should be provided which admits of accuracy without much expense or loss of time.

As lines of communication are seldom unconnected with others of a different principle, the facility of transferring the goods from the one to the other, must also be regarded as essential.

In order to retain a perfectly smooth and hard surface, unencumbered with extraneous obstacles to which the rails near the ground are exposed, it appeared desirable to elevate the surface from the reach of those obstacles, and at the same time be released from the impediments occasioned by snows in the winter season. This also appeared to afford a better opportunity of adjusting and retaining the plane. To elevate two lines of rail for the purpose of supporting a carriage, could not be accomplished at a sufficiently moderate expense: I therefore endeavoured to arrange the form of a carriage in such a manner that it would travel upon a single line of rail, without the possibility of overturning. Having then but one line of surface to retain in its right position, and that so high above the ground as to be completely under the command of hand, the adjustments so much required appeared at once practicable. The only question was, in what manner the surface was to be supported at the required height? After considering on various methods, the supporting of it upon posts, piles, or cast iron pillars, seemed best suited, provided they could be fixed with sufficient firmness, It was evident that if these were fixed in the manner they are usually done, sufficient dependence could not be placed upon them ; but conscious of the enormous weight which a well driven pile would support without yielding, I examined into the circumstances which were necessary to ensure its stability previous to prosecuting the scheme any farther.

When a number of piles are driven near together, it is known they are not so secure as when at a greater distance; so also a pile whose horizontal section is great, is not so effectual in proportion to its size as a lesser one, because if the space taken up by a pile or any number of them, be greater than the compression of the soil admits of, the soil becomes disturbed, loosened, and rises up. The manner of obtaining the most resistance from a pile, is therefore to take out such a portion of the soil as to leave only as much to be compressed by the insertion of the pile as the

compressibility of the soil admits without being loosened.

By this means a pile may sustain a much greater vertical pressure than when driven in the ordinary way. The only thing remaining to be done is to secure its vertical position. If its dimensions are capable of resisting a fracture, this may be accomplished by the depth to which it is driven, equally well as with auxiliary supports on the sides. As cast iron appeared best suited for the material of the pillars, (although in some districts stone or wood may be used) and as in the required form it was not adapted for being driven, I have, on the principle of the foregoing observations, adopted a method which has proved completely effectual even under very unfavourable circumstances.

The form of pillar is seen in figs. 1 and 2; its horizontal section is in the form of a cross, and therefore represents four ribs at right angles to each other. A, fig. 1, (see the plate) is a flanch even with the ground; the ribs beneath its flanch

are notched in order to connect with the material surrounding it. The pillar is inserted into the ground about the same distance as it projects out of it, say 2 feet 6 inches each way. A circular hole is made by taking out a portion of the soil first, and completed by letting fall a conical rammer from an engine, like a small pile engine; this rammer then perfects a conical aperture, and at the same time compresses its sides as far as they admit. A small quantity of sharp broken material is thrown in, and rammed to the height intended for the bottom of the pillar, which is then inserted, and more broken material thrown in, and rammed until the space is filled; see fig. 1. The pillar then, by aid of the notches on the ribs and flanch A at the surface, has firm hold of the conical mass of broken metal, and if it could sink must sink perpendicularly. Now it is evident that more force will be excited in compressing the soil than is equal to any weight which can come upon it at one time; and the surface to be supported being smooth and clean, the motion of the weight will have but little more effect than so much dead weight.

A series of pillars is then fixed in this manner, the ordinary distance of which is ten feet; these vary in height according to the undulation of the ground, within certain limits, their upper extremities being parallel to the intended plane *. This arrangement avoids a great expense in embankments, bridges, culverts, drains, as will be shown hereafter. In a cleft on these pillars are laid reverse wedges, a a, figs. 1 and 2; on which a line of bearers, either of wood or metal, are laid; the upper surface of which then forms a road for the passage of the wheels.

The wheels are two in number, the one placed before the other; the carriage has two receptacles for goods, which are suspended one

---

* Of course the method of fixing the pillars will sometimes vary with the nature of the ground. In passing through a stone country, and where cast iron is expensive, a small stone wall two feet high on the level will frequently answer the purpose.

lars, seemed best suited, provided they could be fixed with sufficient firmness, It was evident that if these were fixed in the manner they are usually done, sufficient dependence could not be placed upon them ; but conscious of the enormous weight which a well driven pile would support without yielding, I examined into the circumstances which were necessary to ensure its stability previous to prosecuting the scheme any farther.

When a number of piles are driven near together, it is known they are not so secure as when at a greater distance; so also a pile whose horizontal section is great, is not so effectual in proportion to its size as a lesser one, because if the space taken up by a pile or any number of them, be greater than the compression of the soil admits of, the soil becomes disturbed, loosened, and rises up. The manner of obtaining the most resistance from a pile, is therefore to take out such a portion of the soil as to leave only as much to be compressed by the insertion of the pile as the

compressibility of the soil admits without being loosened.

By this means a pile may sustain a much greater vertical pressure than when driven in the ordinary way. The only thing remaining to be done is to secure its vertical position. If its dimensions are capable of resisting a fracture, this may be accomplished by the depth to which it is driven, equally well as with auxiliary supports on the sides. As cast iron appeared best suited for the material of the pillars, (although in some districts stone or wood may be used) and as in the required form it was not adapted for being driven, I have, on the principle of the foregoing observations, adopted a method which has proved completely effectual even under very unfavourable circumstances.

The form of pillar is seen in figs. 1 and 2; its horizontal section is in the form of a cross, and therefore represents four ribs at right angles to each other. A, fig. 1, (see the plate) is a flanch even with the ground; the ribs beneath its flanch

riage or vessel separately from the wheels and frame work, without displacing the goods. The receptacles being suspended, their weight preserves their position, and the articles conveyed are therefore not liable to fracture. *A vessel of water may be conveyed without losing a part.* It may be constructed on the side of a public road without occupying more space then can usually be afforded, and its effect need not be diminished by the dust, &c. from the road, as is seen on others. It may be erected on waste and irregular margins of rivers, which on account of the number of culverts and bridges usually required has hitherto been too expensive. From the removal of a great portion of resistance, the effect which can be produced upon it is greater than has before been performed, as seen in the table. The original cost, in those cases for which it is adapted, and where it offers most advantages, will be much inferior to the ordinary plan: in fact, it enables us to obtain a more direct line, and approach nearer the best inclination at a less cost than has before been done, and retain the same in repair at a much cheaper rate. It occupies less land, and is less objectionable to land proprietors. The motion may be impelled by steam, either as a locomotive or stationary power, and well admits of expeditious conveyance with perfect safety.

Having now described the general arrangements, and pointed out the principal advantages which such a disposition presents, I will proceed to describe the details of the construction and application under different circumstances.

In Plate 2, Fig. 1, is a section of the railway, with an end view of a carriage. Fig. 2 an elevation, and Fig. 3 a plan of the same. (The same letters refer to the same parts in the different figures.) A is an upright pillar; *a a*, the adjusting wedges on which the bearer B is laid. The bearers shown in the drawing are of wood, being three-inch deal planks set on their edges, and each extending over two distances of pillars; their upper surface is defended by cast or wrought iron plates.

When the rail has been some time in use, so that all has taken the proper bearing and adjusted, the rail is bolted to the pillars.

D D are the wheels, E E the arms, or axles, trussed by the yoke or fulcrum F and strap G. H H are the receptacles for goods, which are here represented to be of plate iron, and are suspended to the arms by the rods I I I I. To one of the arms a chain K is hooked, and passes through a loop on the end of the box at K, to which a towing rope may be connected. Any number of carriages may then be attached together by chains hooked on to the axles.

This description applies to a carriage of the simplest form, but it is evident the principle admits of great variety according to the nature of the material to be conveyed; all the principle requires is the position of the centre of gravity in relation to the surface of the rail, and that the parts which connect the weights be not flexible.

If one of the receptacles be empty, while the other is full, it is manifest the equilibrium will be destroyed, and the heavy side will come in contact with one of the pillars. Suppose, however, the whole weight to turn upon a point at the surface of the rail, it is evident that a certain difference of load on each side may be applied without either touching the pillar; but the weight does not turn on a point, because the surface on which it rests is at least four inches in breadth, and a greater difference of load may be admitted without any inconvenience: the question therefore is, Whether the difference of load which the principle admits of, be sufficient for practice without inconvenience? The proportions of the parts may be so varied, as to allow of almost any difference; but the proportion represented admits a difference of four hundred weight; and this is much greater than ordinary circumstances require.

Suppose the top of the rail to be flat, if there be unequal loads, the wheels will press harder on one side than on the other. To prevent this, two expedients have been resorted to, the choice of which will be determined by circumstances. The first is to shape the surface of the rail to a slight curvature forming a segment of a circle, about one-sixteenth of an inch in height being sufficient, and shaping the rim of the wheel to correspond with it. A difference of load then alters the angle of the wheels, but, on account of sufficient width being provided in the wheel, it still bears *equally and vertically* on the rail. As the curvature in the rail induces some resistance, although very trifling, I erected one having a flat rail, with the carriage so constructed, that with the difference of load the equilibrium might be preserved on the same principle, by the alteration of the angle, *while the position of the wheels remained vertical.* It being necessary that the wheels have flanches to keep them on the rail, the smallest imperfections either in the rails or the wheels, occasioned a rubbing of them against the sides of the rail, and a much greater resistance than the slight curvature in the first expedient; and, therefore, the first is preferable. It may be objected by some, that part of the force is lost by its not being applied to the centre of the carriage. No doubt some is lost; but the difference of the resistance of a loaded carriage, whose weight exceeds two tons, when it is drawn from the centre, or from its extreme side, does not exceed half a pound.

The circumstance of a horse drawing from a distance, may also, by some, be regarded as objectionable. Undoubtedly it is so at acute bends of the line of railway, but these ought never to be admitted; but provided the horse pull in the direction of the motion of the carriages his distance is favourable. This is well proved in the towing of vessels on canals. The motion of a horse being irregular, there being a variation with each step, he would produce comparatively small effect, if it were possible to connect him close to and in front of the vessel. The length and weight of the rope then forms an elastic medium.

I will now proceed to explain the application of the scheme to practical use.

OF LOADING.

As the two receptacles may not be loaded at the same time, that which is to be loaded first must be supported until the second is full. Where there is a permanent loading place, the carriage may be brought over a step or block; but when it is to be loaded promiscuously, it is provided with a support connected to it, which is turned up when not in use. From the small height of the carriage, the loading of those articles which are done by hand becomes much less laborious.

OF UNLOADING.

The unloading may be done in various ways. One method is shown in Plate 2, and supposes the substance to be coal which is to be discharged into a barge. Figure 4 represents a side view, with a section of part of the shoot and side of the wharf. Fig. 5 is a front view of the same. O, is the shoot, or sloping trough, which receives the coal from the carriage, and conveys it to a barge brought underneath. A, A, Fig. 4, is part of the line of railway brought to the wharf. P, is the last pillar of the line. B, is a rail which turns vertically on a joint on P. Q, is a foot or stop to limit the angle which the rail may assume, by its coming in contact with the shoot. When the rail is in a horizontal position, a carriage may be brought upon it, but there is a projection about the centre of the under side of each box, which, coming in contact with the bar R, Fig. 5, is prevented from proceeding too far. There is also a projecting arm on the end of the rail at S, Fig. 4, which is curved to correspond with the circle of the wheel, so that when the carriage is ready to be discharged, the face of the front wheel coincides with it, and cannot go beyond it. The centre of the carriage being then over the bar R, the rail may be elevated to the required angle, and the suspending rods will remain perpendicular, as shown in the plate. The ends of the boxes being made to open by turning on a joint at the upper side, as seen in Fig. 2, and being secured only by the latch, as at H, Fig. 1, when the carriage is brought to the inclined position, one end of each latch has touched a projection on the shoot which turns them up; the weight of the coals in the boxes then forces the ends open, and both are discharged at the same time; *the attendant has therefore only one motion to perform*, viz. changing the position of the rail, the unlatching and discharging being consequences of the altered position.

The carriage then resumes its horizontal position, and is directed on a siding or branch to make room for another.

When it is intended to unload at various and undetermined parts of the line, the boxes are suspended by their extremities, and turn upon their own centre, so that they discharge sideways.

For some purposes, it may be convenient to open the receptacles at bottom.

BRANCHES,

Turning at Right Angles.

This is done on the same principle as is adopted on other railways, but arranged to accommodate the present plan. Instead of bringing a carriage on to a circular plate turning on a centre, these are brought, one or two at a time, on to a rail which turns upon its centre. In Figs. 6 and 7, *b b*, *c c*, represent parts of a continued line, and *d d* the branch into which a carriage is to be transferred. The intermediate or swinging rail turns on the pillar T, and having a carriage upon it, can be directed to *d*, the branch.

Passings.

When a line is not provided for each direction, passing-places, as on the usual plan, are necessary. Fig. 8, *e e*, is a part of a continued line, *i h*, a side branch. Upon *f* and *f*, as centres, there is a joint rail, which may be directed to *g* or *h* as required, and carriages coming upon *g g* may be passed by others proceeding along *f i h f*. It is of course advisable that the empty carriages turn out if one of the trains be so.

Branches in General.

In cases where two lines must communicate without interruption, or loss of time, a jointed or moveable rail is applied, which will direct to either of two lines. In Fig. 9, *k i*, *m n* are parts of the general line, and *o p* a part of a branch; *i o*, is the joint rail, which turning on the centre, *i*, may be directed to *o*, or *m*.

Crossing Roads.

The expedient necessary in these cases will depend on circumstances; and in arranging the line it will be necessary to choose such places as are best adapted. If the road can conveniently be crossed where it is in deep cutting, or where its surface is sufficiently below the height of the rails, the same, by having a proper span, may pass over the road without interrupting the traffic. If the difference of height be insufficient, other means must be resorted to. If the road to be crossed be a private one, or one on which there is not much traffic, the railway may be made to open at that place by a Gate, as at U in Fig. 7, or by a double gate swinging on a pillar in the centre of the road. If a free passage on the road be always required, the gate will generally stand open, and when a train of waggons on the railway is approaching it, the driver will step forward and shut the gate, and afterwards re-open it, or the last carriage may be made to unlatch the gate, which may be so hung as to fall open, without trusting to the driver. If the road be crossed near the position of a turnpike or parish gate, the same may be made to answer the two purposes.

When no such gate can be admitted, as on public roads with considerable traffic, a small bridge may be built over the railway; and in such a case it will always be desirable to cross where the *public road is above the line of railway,* to avoid raising the road.

Occupation passings, for private convenience are accomplished by merely constructing a rail at any required place, in such a manner as to allow it to be lifted up upon one end as a centre.

Crossing Rivers, Rivulets, and other Water-courses.

If a stream be at all times fordable, no other arrangement will be necessary than an increased span at that place. If not fordable, and the stream be small, or if a drain, the railway will continue on the same construction ; only a platform or small bridge, *sufficient only for the weight of the horse,* must be constructed, but that may be in all cases much lower than the surface of railway, and therefore much shorter than a bridge having the same level.

In crossing a large river, the construction of railway will vary. If a bridge already exist near the spot, advantage may be taken of it as circumstances admit.

1*st*. In some cases the railway may be constructed upon and on one side of the existing bridge. 2*dly*. It may be separate, and near the bridge, that the horse may pass over it. 3*dly*. The parapet wall or balustrade of an existing bridge may become the railway. When an entire new passage is requisite, a bridge must be constructed; but the principle enables that to be accomplished at a much less expense than is necessary in general.

That part of the bridge which is usually the ballustrade, now in fact becomes the bridge for the load; a slight platform being all that is necessary for the weight of the horse. The motion being uniform, and producing little more effect on the bridge than dead weight, less strength is requisite on that account. The frontispiece exhibits one design for the passing of a river. It is partly supported by struts, and partly by wrought iron suspending bars, which extend from the abutement to the end of an inverted king post in the centre. When height is not required for navigation, this becomes a very economical construction. A suspension bridge also very well applies for this purpose; the horizontal line having its bearing upon the curve by means of cast-iron framing.

Junctions with Navigations, Roads, and Railways of other kinds.

The facilities which are offered by the new principle in effecting this operation, constitute one of the leading advantages to be derived from it. As any part of the railway itself may be made moveable, and separable from the rest at pleasure, the same may virtually constitute part of a crane. First, then, let us suppose the railway to unite with a navigation. If the article conveyed admits of being shot out of the carriage to a vessel, the method is already explained under the head of unloading. But if it does not, a terminating rail projecting over the side of a wharf, &c. having received a carriage upon it, may be lowered to any required depth; and the receptacles containing the goods may be released from the wheels and their frame, and being deposited side by side, the wheels may be transferred on to a branch until they are again required. It is obvious many things will not require a complete box having four sides to retain them. Bricks, for example, will only require a platform; slate, a platform and a rail a little above it. Goods which are in cases, crates, &c. will not always require even a platform, as they may at once be suspended from the slings. Suppose the two opposite slings to be continued as low down as the place of the bottom of the receptacles, and connected there by a cross bar, having a roller upon it; it is evident a moveable platform may be laid upon two of these, and when the whole carriage is lowered into a vessel, the platform may be rolled off, if necessary, and the goods deposited in the required position. It would be tedious to enter into a detailed description of the arrangements which may be required for all purposes; it is sufficient to give the general principles, and I trust the foregoing explanation is quite satisfactory.

Secondly; The methods of uniting this principle with roads and railways of other kinds, are generally as follows: The transfer must take place where the road is so much lower than the railway, that a truck may be rolled under the suspended boxes; if not, the rail at which the transfer is to be made must be moveable, and raised as occasion requires. Suppose the moveable rail to be supported and moveable upon two or more parallel joints or arms, after the manner of a parallel ruler, it is manifest that if a carriage be upon it, the same may be raised by rack and pinion, or small crane or jack, conveniently to the required height. If then the truck be brought under the receptacle, it may almost instantaneously be released from the sling, and deposited on that truck.

By a truck, I am supposing a carriage of any description without what is termed the body, it being simply the wheels and frame which connects them.

By this means a railway may be brought near to a town, and the conveyance continued to any part thereof with very little loss of time.

Description of the Frontispiece.

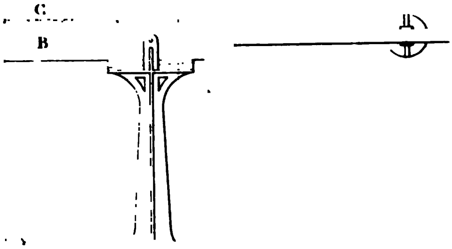
The frontispiece exhibits a portion of railway in use, and the methods of overcoming the several obstacles that most frequently occur. On the left is seen the jointed rail or gate used for crossing private roads. Near this, and on the right of it, is the crossing a fordable stream ; the line then proceeds over slightly undulated ground till it meets with a river, the bridge over which is adapted particularly for this purpose. The next peculiarity is a turning rail, by which the waggons are transferred, two at one time, on to a branch at right angles. The

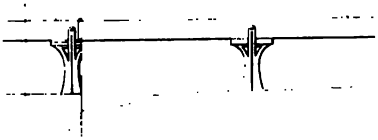
branch is seen constructed parallel to a public road, to which it constitutes a fence. The line then passes under the public road, and is ultimately seen skirting a hill side, without requiring the usual necessary side-cutting.

J. Wallen

THE END.

LONDON:
PRINTED BY JOHN HILL, PATERNOSTER ROW.





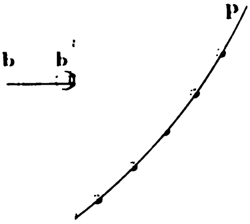
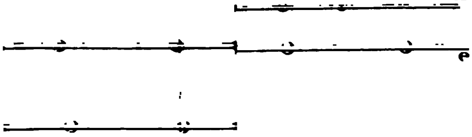


Fig. 8.



E. Turrell, sculp.

TF 694 .P17
Description of a railway on a
Stanford University Libraries
3 6105 041 654 802

HOPKINS RAILWAY
LIBRARY.

For
USE IN LIBRARY
ONLY
DO NOT REMOV
FROM LIBRA